EFFECT OF DIFFERENT FARMING PRACTICES AND MULCHES ON PRODUCTION OF STRAWBERRY UNDER WILD POMEGRANATE-BASED AGROFORESTRY SYSTEMS

Thesis

by

ANSHUL THAKUR
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Dr Prem Prakash
(Assistant Professor)

Department of Silviculture and Agroforestry
College of Forestry
Dr Yashwant Singh Parmar University of Horticulture and Forestry
(Nauni) Solan (HP) - 173 230 India

CERTIFICATE-1

This is to certify that the thesis titled " **Effect of different farming practices and mulches on production of strawberry under wild pomegranate-based agroforestry systems** " submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science (Forestry)** in the discipline of **Silviculture and Agroforestry** of Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP)-173 230 is a bonafied research work carried out by **Ms. Anshul Thakur (F-2021-07-M)** daughter of **Sh. Kuldeep Kumar** under my supervision and no part of this thesis has been submitted for any other degree or diploma.

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

Place: Nauni, Solan
Date:

(Dr. Prem Prakash)
Major Advisor

CERTIFICATE - II

This is to certify that the thesis entitled, **"Effect of different farming practices and mulches on production of strawberry under wild pomegranate-based agroforestry systems"** submitted by **Ms. Anshul Thakur (F-2021-07-M)** daughter of Sh. Kuldeep Kumar to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) – 173 230 India in partial fulfilment of the requirements for the award of degree of **Master of Science** in the discipline of **Forestry (Silviculture and Agroforestry)** has been approved by the Advisory Committee after an oral examination of the student in collaboration with the External Examiner.

30/09/23

Dr. Prem Prakash
(Assistant Professor)
Chairman, Advisory Committee

30/09/2023

Dr. Aalok Gulabrao Yewale
External Examiner

Members of Advisory Committee

30/9/2023

Dr. D.R. Bhardwaj
Professor and Head
Department of SAF

30/9/23

Dr. Rohit Bishist
Associate Professor
Department of SAF

30/9/23

Dr. Pramod Verma
Assistant Professor
Department of Fruit Science

Professor and Head
Department of Silviculture and Agroforestry

Dean
College of Forestry
Dr. Yashwant Singh Parmar University of Horticulture of Forestry
Nauni – Solan (HP) - 173230

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(Anshul Thakur)

CONTENTS

LIST OF ABBERIVIATIONS USED

%	:	Per cent
ºC	:	Degree Celsius
ANOVA	:	Analysis of Variance
ºB	:	Degree Brick
B:C	:	Benefit cost ratio
CAN	:	Calcium ammonium nitrate
CD	:	Critical difference
Cm	:	Centimeter
Cm^2	:	Centimeter square
cv.	:	Cultivar
Df	:	Degree of freedom
dSm^{-1}	:	Deci Siemens per meter
EC	:	Electrical conductivity
et al.	:	Etalia (Co-workers)
FYM	:	Farm yard manure
g	:	Gram
ha^{-1}	:	Per hectare
HP	:	Himachal Pradesh
i.e.,	:	That is
K	:	Potassium
Kg	:	Kilogram
m	:	Meter
m^2	:	Meter square
ml	:	Milliliter
mm	:	Millimeter
MOP	:	Muriate of potash
MT	:	Metric tonnes
N	:	Nitrogen
NS	:	Non-significant
No.	:	Numbers
OC	:	Organic carbon
P	:	Phosphorus
pH	:	Puissance d' Hydrogen
q	:	Quintal
RBD	:	Randomized block design
RDF	:	Recommended dose of fertilizer
Rs	:	Rupees
SPAD	:	Soil plant analysis development
Sm	:	Soil moisture
SSP	:	Super single phosphate
t	:	Tons
TCC	:	Total chlorophyll content
TSS	:	Total soluble solids
var.	:	Variety
viz.	:	Videlicet (namely)
yr	:	Year

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Chapter-1

INTRODUCTION

Horticulture based agroforestry-based systems are multifunctional in nature and provide a wide range of economic, socio-cultural and environmental benefits. Agroforestry is a system or modern, scientifically advanced technology for farmers to enhance the security of socioeconomic conditions and environmental cleanliness by cultivating all components in one fixed area. Agroforestry practices also provides great potential for finding solutions to the world's challenges of self- sufficiency and the supply of fundamental needs (Singh *et al*. 2021). Agroforestry increases soil-related microbial activity through the impact of the trees, organic matter deposition, the presence of root exudates, and the variety of litter quality, all of which contribute to improving the soil quality. Agroforestry helps in the mitigation of erosion by reducing runoff, intercepting rainwater, and binding soil particles together (Fahad *et al*. 2022).

Integrating fruit trees into farmlands is a promising agroforestry technique known as agri-horticultural land use system, where the fruit tree serves as the primary crop. (Dwivedi *et al*. 2007). In comparison to monocropping, the fruit tree-based agroforestry method seems superior because of the benefits it offers for the economy and the environment as well as its less susceptible attributes to outside influences (Anshiso *et al*. 2017). It is beneficial to combine horticultural crops with trees and pasture because it can prevent soil erosion and increase soil fertility and yield by consistently adding organic matter. The appropriate association of horticultural crops, trees, and pasture can certainly improve microclimate while also can improve the nutritive quality and palatable characteristics of pastures and grass species (Raj *et al*. 2019).

Wild pomegranate (*Punica granatum* L.) is commonly known as 'Daru' belongs to the family Punicaceae. Wild pomegranates are broadly dispersed in drier and sub-marginal land of mid-hill regions of outer Himalaya, where the climate is relatively hot. In India, wild pomegranates are usually found in large areas of Himachal Pradesh, Jammu and Kashmir, and Uttarakhand at elevations between 900 and 1800 meters above mean sea level.it is widely distributed in Mandi, Solan, Sirmour, Kullu, Chamba and Shimla districts of Himachal Pradesh (Thakur *et al*. 2011). The sole commercial fruit grown in the Himalayan mid-hills is the wild pomegranate, which contains several phytonutrients in the form of anthocyanins, phenolics, and flavonoids that provide antioxidant characters in addition to color. Arils, the edible part of wild pomegranate are abundant in organic acids, vitamins, sugars, anthocyanins and bioactive substances. Because of the acidic character of arils, they are dried and used to prepare condiments (anardana) (Sharma and Thakur, 2016).

Strawberry (*Fragaria* × *ananassa* Duch.) cv Camarosa belongs to the family Rosaceae. Strawberry is majorly grown in nations with temperate or subtropical climate. Strawberries are rich in fiber, folic acid, vitamin C and a number of other antioxidants but low in calories. Strawberry flowering response to photoperiod, they are of two types: the short-day type which starts flowering when photoperiod is less than 14hr, and the day neutral type, which starts flowering under any photoperiod (Darnell 2003). It is commercially cultivated in states of Haryana, Maharashtra, Jammu Kashmir, Mizoram, Meghalaya, Madhya Pradesh, and Himachal Pradesh. In Himachal Pradesh, strawberry is majorly produced in Paonta valley and Rajgarh. According to 2019-20 estimates the area and production under strawberry is reported to be 1000 ha and 5000 MT, respectively (National Horticulture Board). Strawberry is a sweet and nutritious fruit which can be raised under varied climatic conditions. It is primarily a crop of temperate climate but can be grown in sub-tropical climate and even at high altitudes of tropical climate. In humid or dry region, it grows up to an elevation of 3000 meters above mean sea level. The optimum day temperature ranges from 22ºC to 23ºC and night temperature from 7ºC to 13ºC which is preferred for maximum growth and development in strawberry.

Application of chemical fertilizers is now considered as a necessary agriculture tool/ practice, but the continuous use over a long period of time causes a detrimental impact/effect on the physicochemical and soil biological properties. Moreover, it destabilises the structural and functional diversity of microorganisms present in soil. Plants are unable to grow nutritious or strong stems, and as a result of the conditions created, they have a lesser chance of surviving and are more prone to diseases and pests. Chemical fertilizers prevent plants from absorbing enough water, resulting in root burning (Pahalvi *et al*. 2021).

Masanobu Fukuoka, a Japanese scientist and philosopher, was the first person who pioneered natural farming. In India, Subash Palekar introduced zero budget natural farming in 1990s. Subhash Palekar Natural Farming (SPNF) is a farming approach that improves soil fertility through a variety of agro-ecological principles such as diversification, nutrient recycling, and increased beneficial biological interactions (Rana *et al*. 2021). Natural farming is an environmentally sustainable system. It aids in preserving the health of the soil, controls pests and helps farmers escape the debt traps (Korav *et al*. 2020). In order to make agriculture economically feasible and profitable, SPNF was introduced in Himachal Pradesh (HP) as part of the Prakritik Kheti Khushhal Kisan (PK3) Yojna, which was introduced in 2018 (Chandel *et al*. 2023). To tackle such problems, organic farming was proposed as a better and more sustainable alternative. The Himachal Pradesh government has even launched a number of programs like zero budget Natural Farming to lower the cost of farming.

The global temperature is increasing over the past years which is directly or indirectly affecting the water table, the application of organic mulches helps in reducing the direct evaporation from the soil surface. Organic mulches such as straw, bark and composted municipal green waste can provide effective weed control. Weed suppression by organic mulches can be due to the physical presence of the materials on the soil surface and/or the action of phytotoxic compounds generated by microbes (Ozores-Hapton *et al*. 2001) as organic mulches decompose over time so periodic re-application must be done to suppress weeds. A mulch that can be broken down by microorganisms and is composed of renewable organic materials is referred to as biodegradable mulch (Iriany *et al*. 2018). Mulches increases the length of the runner stolon, the quantity of leaves, and the area of the leaves of the runner plantlets (Angrez and Gaur, 2013). Mulching is one of the cultural practises used in strawberry production that is most important since it affects fruit quality, yield, and plant growth (Meena *et al*. 2023). Organic mulching is one of the effective techniques that might help horticultural growers in increasing output of high-quality produce (Ranjan *et al*. 2017). (Burkhard *et al*. 2008) also reported that pine needle mulch was significantly much more effective in suppression of weeds than any other mulch.

Poplar mulch changes the soil's cation exchange capacity, improves soil structure, and increases soil organic matter (Kumar *et al*. 2014). Fruit based AFS have received very less of research even after being a common practice on farms of small land holding farmers. (Bellow *et al*. 2008).

Thus, keeping in mind, the economic importance of wild pomegranate along with field crop, the present study entitled **“Effect of different farming practices and mulches on production of strawberry under wild pomegranate-based agroforestry systems”** was carried out with following objectives:

Objectives:

i) Effect of manures and mulches on production of strawberry under wild pomegranate-based agroforestry-based system.

ii) To study the effect of manures and mulches on the nutrient status of soil.

iii) To calculate the bio-economic appraisal of the fruit-based agroforestry system.

Chapter-2

REVIEW OF LITERATURE

Fruit based agroforestry systems are emerging as a new sustainable and effective management approach in the field of agroforestry as it ensures high economic returns while keeping land management and environment in check. It also helps in conserving soil, regulates nutrient cycling thus, improving soil quality and nutrient status of soil. The relevant review of literature on the topic **"Effect of different farming practices and mulches on production of strawberry under wild pomegranate-based agroforestry systems"** has been reviewed under the following heads:

2.1 Effects of manures and mulches on production of Strawberry

2.2 Performance of field crops under fruit-based agroforestry system

2.3 Effect of manures and mulches on nutrient status of soil

2.4 Bio-economics of agroforestry systems

2.1 Effects of manures and mulches on production of Strawberry

Hassan *et al*. (2000) studied the effect of different mulches on the yield and quality of 'Oso Grande' strawberry (*Fragaria× ananassa*). They revealed that strawberry plants mulched with black polythene produced the highest yield, followed by those mulched with transparent polythene and Saccharum residues. The control produced the lowest yield. The black polythene mulch treatment resulted in the production of fruits of the greatest quality.

Kikas and Luik (2000) studied the influence of different mulches on Strawberry yield and beneficial entomofauna. They observed the effect of different types of mulches like black plastic, bed carpet, wooden chips, straw, and un-mulched control on yield of strawberry and the damages caused by plant bugs and seed beetles on berries. The plots were not subjected to any sort of chemical treatments. It was seen that the use of black plastic mulch produced best results in *Senga Sengana*.

Kirnak *et al*. (2001) conducted an experiment to study the role of mulches in the physiology and macro-nutrition of strawberry. It was observed that both black polythene mulch and wheat straw mulch increased fruit output, fruit size, plant dry matter, leaf area index, and chlorophyll concentrations. It was concluded that application of mulches in combination of black polythene mulch and wheat straw mulch improved the concentration of nutrients and fruit yield in field grown strawberries.

Forcella *et al*. (2003) investigated the biological mulches for managing weeds in transplanted strawberry. It was revealed that 1-ply woolen fabric was the most effective alternative treatment, as it effectively removed weeds from rows, encouraged daughter plants roots and allowed maximum fruit yields. Results revealed that canola integration produced great fruit output and controlled weed invasion.

Mathad and Jholgikar (2003) studied the effect of synthetic and organic mulches in improving growth, yield and quality of strawberry under subtropical ecosystem. It was revealed that planta mulched with polythene performed better than those mulched with organic materials. Plants covered in white over black laminated polythene mulched yielded more berries with a high mean fruit weight. When compared to biological mulches the yield of marketable berries was 10-13% higher in synthetic mulches. It was also that all mulched plots increased TSS, TSS/acid ratio and anthocynin pigmentation.

Skupien and Oszmianski (2004) studied six strawberry cultivars grown in Northwest Poland in accordance with conventional farming methods in order to determine how well Senga Sengana performs in comparison to Dukat, Elkat, Selva, Elsanta and Kent. It was observed that kent berries had the highest concentration of total sugar, total polyphenol, total anthocynin and ellagic acid derivatives. While Elsanta had the highest concentrations of vitaminc and ellagic acid. In comparison to ither cultivars Duckat exhibited the highest dry weight and soluble solids. Elsanta and Elkat berries were found to have the highest brightness, redness, chromaticity and hue angle values.

Moor *et al*. (2004) studied the effect of mulching and fertilization on the quality of strawberries. The results revealed that fertilization increased the yield of first grade fruits with both mulches. Fertilization had a favorable impact on the vitamin C content of plastic mulch. Fruit damage was reduced by fertilization using straw mulch. The number of solube solids was not impacted. It is a cost- effective and efficient strategy to prevent a reduction in fruit size in the third year of production. It was also noted that plant age had a detrimental impact on the vitamin C level.

Turhan and Eris (2005) studied the changes in micronutrients, dry weight and chlorophyll contents in strawberry plants under salt stress conditions. It was found that in comparison to control treatment the leaf dry weight increased in NaCl treatments. No effect on the amount of total chlorophyll was seen. It was noted that iron and manganese content was increased after salt treatments.

Daugaard (2008) scrutinized the effect of mulching materials on yield and berry quality in organic strawberry production. It was found that the yields of the biodegradable plastic and regular black plastic were similar but the biodegradable plastic decomposed throughout the first growing season. It was noted that paper wool slowed plant growth significantly. Results revealed that the usage of straw mulch out of all mulch materials proved to be effective alternatives to that for weed management.

Balci and Demirsoy (2008) studied the effect of organic and conventional growing systems with different mulching on fruit yield and fruit quality in strawberry cultivars. They revealed that fruit produced with organic system had higher levels of soluble solids and Vitamin C. The organic system had less fruit that was rotted. There was no difference in fruit weight or titrable acidity content between conventional and organic farming. It was also noted that in the organic system Camerosa performed better than Sweet Charlie in terms of yield and fruit quality. It was concluded that organic strawberry farming is suggested due to the environmental and human health benefits and higher market price.

Ogendo *et al*. (2008) investigated the interaction of farmyard manure (FYM) and plant population density (PPD) effects on soil characteristics and productivity of mulched strawberry in a tropical climate. They determined the effects of FYM and PPD on soil characteristics, growth, fruit yield and quality of mulched strawberry under tropical conditions. It was noted that manure has increased soil CEC in a substantial way. The number of leaves grew significantly. The number of runners was decreased significantly but the quantity and weight of berries were significantly increased. The interaction between FYM and PPD significantly impacted TSS.

Keutgen and Pawelzik (2008) examined the quality and nutritional value of strawberry fruit under long term salt stress. It was observed that the decrease in mean fruit weight, the fruit dry matter, TSS and sweetness index all remained constant. It was also noted that there was an increase in lipid peroxidation, antioxidant capacity, antioxidant pools and specific minerals.

Umar *et al*. (2008) studied the impact of integrated nutrient management on strawberry yield and soil nutrient status. It was recorded that there was a great increase in soil organic carbon and available nutrient content by FYM, urea and azotobacter applied alone or in combination. The highest organic carbon content of 0.63% was recorded. The highest N and P was observed when 25 % N was applied as FYM + 75 % N. The maximum strawberry yield of 372.89 q/ha was observed with the application of full N as urea along with azotobacter.

Umar *et al*. (2009) examined the effect of FYM, Urea and Azotobacter on growth, yield and quality of strawberry cv. Chandler. It was noted that when 25 % nitrogen in the form of FYM was applied with azotobacter, plant attained the height of 21.24 cm, 28.16 cm of plant spread, 74.95 cm^2 of leaf area15.87 g of fruit weight and 37.62× 28.01 mm of fruit size. It was also observed that maximum yield of 372.89 g per plant was obtained with the usage of nitrogen in form of urea along with Azotobactor.

Ravneet and Sarabjeet (2009) studied the impact of mulching on growth, fruit yield and quality of strawberry. It was noted that black polythene produced the most leaves, flowers, fruits and fruit yield followed by clear polythene and paddy straw. It was concluded that black polythene mulch had highest TSS, sugar percentage and ascorbic acid percentage.

Univer *et al*. (2009) examined the living grass mulch in strawberry cultivation. The effectiveness of several living mulches was examined. The natural grass cover, red fesue, Kentucky bluegrass, perennial ryegrass, timothy, orchard grass and white clover were compared with other living mulches. It was observed that living grass mulches influenced strawberry yield. It was also revealed that strawberry yield was decreased by orchard grass, perennial ryegrass and timothy.

Yadav *et al*. (2010) investigated the integrated nutrient management for strawberry cultivation. The results revealed that treatments had no impact on the number of leaves per plant, the length of the flowering period or the size of the berries. The highest plant development traits were found in plots fertilized with inorganic fertilizer. Because of its lower production cost, N substitution by FYM gave a higher B:C ratio than vermicompost.

Ayesha *et al*. (2011) evaluated the influence of different growth media on the fruit quality and reproductive growth parameters of strawberry. The evaluation indicated that the various growing media also had an impact on the strawberry plants' various reproductive growth parameters. It was also found that medium based on coconut coir dust proved to be the best medium. The T_4 (Soil + Silt + Coconut Coir Dust) treatment had a positive impact on other critical growth stages. The T_4 growing media also had a significant impact on the color of the fruits, which were brighter and more reddish due to maximum values of brightness. It also increased the ascorbic acid content of fruit. The total soluble solids and total sugars both were increased in the T_1 growth medium. T_4 also had a substantial impact on total sugars in strawberry fruits.

Kumar *et al*. (2012) studied the influence of mulching and irrigation level n water use efficiency, plant growth and quality of strawberry. It was noted that irrigation promoted plant development, accelerated blooming, increased fruit size, yield, increased TSS and increased ascorbic content. Plants mulched with black polythene film experienced significantly better growth, early flowering and fruiting, larger fruit production and higher yield. Crown height, plant spread and leaf area all have been impacted by the relationship between irrigation level and mulching. It was revealed that under irrigation mulched with black polythene, strawberries produced larger fruit and higher yield, higher TSS and ascorbic acid content.

Nazir *et al*. (2012) studied the effect of integrated nutrient sources on soil nutrient status and microbial population in strawberry field. Treatment T_2 (Poultry Manure + Azotobacter + Phosphorus solubilizing bacteria + Oil cake) produced the highest plant growth and fruit yield followed by treatment T_4 (Poultry Manure + Azospirillum + wood ash + Phosphorus solubilizing bacteria + Oil cake). Treatment T_4 showed increase in available nitrogen and phosphorus. The treatment T_2 showed the highest potassium levels. It was concluded that treatments T_2 and T_4 can be used for increased yield and sustainability based on performance.

Angrej and Gaur (2013) studied the effect of organic mulches on runner production of strawberry. The results revealed that all of the organic mulches greatly improved strawberry runner production. The percentage increase in runner plantlets compared to paddy straw, sugarcane trash, sawdust and dry grass mulch were 33.33, 27.78, 18.00 and 14.00

respectively. The length of the runner stolon, number of leaves and leaf area of runner plantlets were all enhanced by organic mulches.

Florentia *et al*. (2013) evaluated the mulch and fertilizer effect on Vitamin C concentration and acidity in strawberries. It was noted that the maximum Vitamin C concentration was found in Kimberley variety under agro-textile mulch and which organically fertilized. It was also noted that Vima Xima cultivar showed high percentage of organic acids, citric acid when cultivated with agro-textile mulch.

Taparuskiene and Miseckaite (2014) evaluated the effect of mulch on soil moisture depletion and strawberry yield in Sub-humid area. The mulches of organic wheat straw and non-organic black plastic were used. The study found that soil moisture content varied greatly and top soil layer mulching was highly effective in the field to promote growth and obtain a high fruit production. It was noted that within three years the soil moisture content in the active soil layer was highest in the field mulched with straw, lowest in the field without mulching and equal in the plot mulched with black polythene. It was also noted that the yield from black polythene layer mulched field was greater than the yield from the non-mulched field and higher than the yield from the straw mulched plot after two years.

Kumar *et al*. (2015) examined the impact of organic manures and biofertilizers on growth and quality parameters of strawberry. The combination of vermicompost and phosphate solubilizing bacteria showed the highest plant height, leaves per plant, primary branches per plant, secondary branches per plant, first flowering, flowers per plant, first fruit setting. The total soluble solids, titratable acidity, vitamin C, total sugars and juice content were also considerably impacted by the treatment combination of vermicompost and phosphate solubilizing bacteria.

Kumar *et al*. (2015) investigated the effect of different levels of NPK in combination with FYM on quality of strawberry. They indicated that T_4 (N0F1) exhibited the highest TSS, ascorbic acid, specific gravity and lowest acidity and pH followed by T_{10} (N2F2). The control had the lowest values recorded. It was recorded that T_7 (N2F1) was the best treatment combination for improving fruit production.

Phet and Mpuat (2016) studied the efficacy of mulches on soil modifications, growth, production and quality of strawberry. Results revealed that all mulches, including rice husk, white polythene showed good results compared to no mulch in terms of plant growth, yield and quantity. It was also seen that black polythene mulch proved similarly good in preserving soil moisture against evaporation. The highest plant spread, biomass, fruit size, fruit yield, total sugar, vitamin C and anthocyanin content was observed under black polythene mulch indicated that elevated soil temperature acts as a catalyst for root activities such as water and nutrient uptake. It was concluded that black polythene mulch with the thickness of 25 microns can be recommended as an important practice for resource conservation, increased growth, yield and quality of strawberry.

Sharma and Negi (2019) examined the effect of organic manures and inorganic fertilizers on the plant growth of strawberry (*Fragaria* × *ananassa*) cv. Shimla delicious under mid-hill conditions of Uttarakhand. It was revealed that most runners per plant were observed in the treatment T_4 which was 25% of NPK inorganic fertilizer and 75% organic manure. It was also observed that treatment T_4 showed that fruit juice exhibited the highest level of acidity.

Maity *et al*. (2020) studied the application of liquid manures on growth of various crops. It was seen that liquid manure is rich source of micro and macro nutrients, it consisted of growth promoting factors like auxin, gibberellins and beneficial microorganisms. It was also revealed that use of Panchgavya, jeevamrit and compost tea enhanced the biological efficiency and efficacy of crop and improved the soil health. It also enhances the productivity of different crops and suppresses the growth of various plant pathogens by producing antibacterial and antifungal compounds.

Mohan *et al*. (2020) examined the effect of nutrients on growth and yield of strawberry. It was revealed that the plant height, spread and the quantity of leaves, flowers and clusters per plant were all significantly different between the treatments. It was also seen that T_7 (FYM 30 t/ha + NPK 50:40:75 kg/ha) and T_8 (FYM 30 t/ha + NPK 75:20:100) were comparable to and superior to other treatments in terms of fruit number and yield per plant.

Neri *et al*. (2021) examined the strawberry living in an organic vineyard. It was revealed that the use of strawberry plants as a living mulch under the grapevines along the row assured a substantial soil cover without affecting the physiology or yield of the grapevines. Strawberry plants grew slowly in the summer and readily survived the winter frost while effective

Singh *et al*. (2022) examined the effect of FYM and vermicompost on growth and yield on strawberry (*Fragaria× ananassa*) cv. Camerosa. Results revealed that the maximum plant height recorded was 16.19cm, spread 35.06cm, number of branches per plant 19.96, number of leaves per plant 17.77, number of fruits per plant 18.14, yield per plant 208.07 g and yield per hectare 58.94 q/ha have all been observed.

Singh *et al*. (2022) examined the effect of nutrients and mulches on qualitative aspects of strawberry (*Fragaria × ananassa* Duch) cv. Chandler. It was noted that yellow polythene mulch performed best for the majority of physico-chemical parameters followed by black polythene mulch over controls. It was also observed that yellow polythene mulch showed noticeably greater vegetative growth, fruit yield and berry size than black polythene mulch. Black polythene mulch was found to be superior in terms of fruit quality, sugar content, vitamin A content and anthocynin content.

Semwal *et al*. (2022) examined the effect of mulching on growth, yield and economics of strawberry under subtropical conditions of Uttarakhand. It was revealed that mulching with black polyethene was more suited for the growth and yield characteristics of strawberry cultivation. It can be concluded that black polythene mulch, when compared to other mulch materials was found to be the most effective for influencing a variety of growth parameters, including number of leaves per plant, number of flowers per plant, leaf area, number of runners per plant, yield parameters like number of fruits per plant, fruit weight, total yield per plot, total yield per hectare and economics.

2.2 Performance of field crops under fruit-based agroforestry system

Bisht *et al*. (2000) studied the performance of ginger (*Zingiber officinale*) and turmeric (*Curcuma longa*) with fodder tree based silvi-horti system in hills. Study demonstrated that various fodder trees had a major effect on the yield of ginger and turmeric. With Quercus leucotrichophora, ginger and turmeric both produced the highest yield. However, *Bauhinia variegata* produced the greatest amount of green forage among the trees. The amount of light filtered by the trees and the production of ginger and turmeric were negatively correlated. It was found that growing *Quercus leucotrichophora* with turmeric and ginger was the most advantageous and profitable silvi-horticultural combination.

Bellow *et al*. (2008) analysed the adoption potential of fruit-tree-based agroforestry on small farms in the subtropical highlands. They observed that families with greater land holdings found fruit-tree-based agroforestry to be more attractive. In areas with smaller family land holdings improvements in fruit tree yield and interspecies competition were more significant. The complementarily of production with the leading maize (*Zea mays*) crop, home consumption of fruit, and the possibility to create additional revenue on restricted land holdings were recognized as factors favoring the development of fruit-tree-based agroforestry.

Hossain *et al*. (2014) examined the screening of tomato varieties for fruit tree-based agroforestry system. Four varieties of tomatoes were intercropped under guava, mango and olive orchards. It was reported that control plot had highest yield and lowest in olive plot. The financial outcomes of the tomato production system based on fruit trees revealed that the net return and BCR of the guava and mango systems were greater than those of the control and olive systems. The amount of nutrients in soil was found to have risen. Agroforestry systems based on fruit trees had somewhat greater levels of organic carbon, nitrogen, accessible phosphorus, potassium, and sulphur than the control. It was observed that fruit tree-based agroforestry systems altered the amount of light available for tomato cultivation.

Nayak *et al*. (2014) evaluated the economics and yield performance of short duration fruit and medicinal crops under agri-silvicultural system in rain fed uplands of Odisha. It was revealed that Pineapple produced the most fruit under mangium and the least under gamhar. Aloevera produced the most fresh leaves under mangium, which is statistically equivalent to gamhar. In open conditions, kalmegh recorded the highest dry plant yield, followed by gamhar and mangium. Mangium, gamhar, and mango ginger showed the highest rhizome yield under open conditions.

Tripathi *et al*. (2017) conducted an experiment to study the effect of organic manures on soil physicochemical properties under fruit-based agroforestry system. Results revealed that available macronutrients were significantly affected by intercropping of medicinal herbs and the application of organic manures under Peach based Agroforestry system as compared to control.

Kumar *et al*. (2019) examined the integration of fruit trees in agroforestry for sustainability and profitability of farming systems in arid and semi-arid regions. They revealed that fruit tree-based agroforestry system provides with fruits, timber, food, fuel, fodder and also generate employment opportunities, provides nutritional security, reduce greenhouse emissions and improves soil health. They concluded by stating that fruit-based agroforestry can play a crucial role in crop diversification.

Tomar *et al*. (2020) analysed the studies on Horti-agricultural System in a Mid altitude of Meghalaya. It was revealed that peach had the highest recorded height, collar diameter, and crown spread, followed by guava, then Assam lemon. The average grain production and total yield were higher in the control plots than in the fruit tree understory plots. It was also noted that in understory plots, weed ground cover was highest in control plots.

2.3 Effect of manures and mulches on nutrient status of soil

Bhadoria *et al*. (2003) analyzed the relative efficacy of organic manures on rice production in lateritic soil. The FYM produced the highest grain and straw yields. The amount of available N, P, K, and micronutrients varied among the organic manure. When compared to all other commercial manures and inorganic fertilizers, FYM considerably increased the uptake of N, P, and K by rice plants. The tolerance of rice plants to attack by diseases and pests, measured in terms of grain yield was highest in the treatment with FYM. It was found out that among the commercial manures tested, Processed City Waste showed the most ability and emerged as a possible substitute for FYM.

Burkhard *et al*. (2008) studied the effects of pine-needle and compost mulches and weeds on nitrogen dynamics in an organically-managed highbush blueberry field. The use of heavy application of different mulches (pine needles and diversified composts) for organically managed highbush blueberry (HBB) and their effects on weed growth and N acquisition, HBB growth, leaf tissue N, berry yield and quality, and soil pH, moisture, and temperature. It was revealed that the weeds competed fiercely for the mineral nitrate in the soil, lowering its level by 71%. The longest-lasting elevated soil mineral N levels were seen. Mulch made of pine needles was discovered to be the most effective method of reducing weed competition.

Sharma and Kathiravan (2009) evaluated effect of mulches on soil hydrothermal regimes and growth of plum in mid hill region of Himachal Pradesh. They revealed that all mulches maintained much higher soil moisture contents than the unmulched control, and the highest layer exhibited the greatest in situ moisture conservation. Among mulch. Transparent polythene recorded a higher temperature and mulches had a significant impact on soil temperature. Under Black Polythene and Bicolored Polythene, weed growth was efficiently controlled and was at a minimum. Mulches had a substantial impact on plant growth as measured by annual shoot growth and fruit output, and BP produced more. It was also seen that field grass and pine needles both contributed similarly to an increase in yield compared to the unmulched control.

Essien *et al*. (2009) examined the effect of organic mulch materials on maize performance and weed growth in the derived savanna of south eastern Nigeria. They analysed the effect of organic mulch materials on the performance of maize and weed growth in the derived savanna. The results revealed that the Graminaea, Asteraceae and Solanaceae weed families were the most common. The majority of the weeds were annual species with wide leaves and grasses. With the exception of no application, all treatments significantly reduced the amount of weed growth. Investigation indicated the importance of organic mulch materials for crop performance and weed suppression.

Li *et al*. (2010) evaluated organic mulch and fertilization affect soil carbon pools and forms under intensively managed bamboo (*Phyllostachys praecox*) forests in southeast China. They concluded that continuous use of organic mulch throughout the winter raised the overall soil organic C content while lowering its stability. In bamboo forests that are actively maintained, organic leftovers are mulched to increase the storage of organic carbon in those forest ecosystems.

Singh *et al*. (2010) evaluated the efficacy of organic mulches on soil properties, earthworm population, growth and yield of Aonla cv. NA7 in semi-arid ecosystem. The study revealed that paddy straw mulch followed by maize straw and grasses had produced good outcomes in terms of soil moisture, physico-chemical characteristics of soil, and earthworm population in basin soil. When compared to the other mulching treatments paddy straw mulches were found to be more successful at promoting greatest growth and development. The largest yields were achieved by plants mulched with rice straw in 2005 and 2006, at 9.0 kg per plant and 42.15 kg per plant. Paddy straw and maize straw mulch had the highest concentrations of TSS, total sugar, total phenols, and vitamin C, respectively. Paddy straw and maize straw were the two most effective organic mulches that were tested. In order to boost the production of Aonla orchards in rain fed conditions within a semi-arid ecosystem the long-term usage of paddy straw as mulch material needs to be promoted due to its superiority over other organic mulches.

Solomakhin *et al*. (2010) examined the organic mulch in apple tree rows as an alternative to herbicide and to improve fruit quality. Organic mulches like sawdust, pine bark, grass clippings were used for the experiment. The three organic mulches reduced the number of emerged weeds by 5-30% compared to the manually weed control, which organic mulches an environmentally friendly alternative to herbicide to control 25-30 weed species. When compared to manual weeding, the three organic mulches improved soil properties, conserved moisture, and increased N, P, and K content.

Uwah and Lwo (2011) examined the effectiveness of organic mulch on the productivity of Maize (*Zea Mays* L.) and weed growth. Five mulch treatments were used. Five mulch rates (0, 2, 4, 6, and 8 t/ha) were laid in a randomized complete block design with four replications. Soil moisture reserves were highest at the 8 t/ha mulch rate, followed by 6 t/ha rate. The unmulched control plots had the highest weed infestation, lowest soil moisture reserves, shortest plants and least amount of leaves/plant. Weed infestation at the unmulched plots were higher by as much as more than 6 and 11 times those at 6 and 8 t/ha rates respectively.

Singh and Bal (2011) Studied the effect of mulches on soil NPK availability and leaf nutrient levels in Indian Jujube. The treatment with black polythene + glyphosate at a rate of 1 L/ha resulted in the highest leaf N concentration ever recorded in jujube leaves. With paddy straw mulch jujube plants had the highest available soil P and K. Black polythene mulch had the highest levels of soil moisture and maximum amounts of available nitrogen. Black polythene mulches performed the best out of all the mulches used in reducing weed growth. They concluded that the best option for jujube orchards is black polythene mulch because it increases water content in content, inhibits weed growth, and promotes soil NPK availability and levels of nutrients in Indian jujube leaves.

Maggard *et al*. (2012) evaluated the tree-based mulches and their leachate suppress weed seed emergence. They studied the effect of eastern redcedar, hardwood, pine bark nugget, pine, eucalyptus, cypress, and red-dyed mulches on the growth of large crabgrass, johnsongrass, common lambsquarter, and redroot pigweed. Leachate treatments were less effective than mulch, although they reduced weed emergence by 16 % on average across all treatments. Red-dyed mulch leachate reduced weed emergence by 41 %, the most of any mulch leachate tested, whereas eastern redcedar leachate reduced the growth by 23 %. It was observed that the wood mulch treatments reduced weed emergence when compared with without mulch.

Kumar (2014) examined the effect of different organic mulching materials on soil properties of NA '7' AONLA (*Emblica officinalis* Gartn) under rainfed condition of Shiwalik foothills of Himalayas India. It was reported that mulches had no impact on the soil properties viz soil pH and electrical conductivity where as soil organic carbon, available N, available P, available K had significant effect. It was also revealed that application farm yard manure increased soil organic carbon and available nutrients.

Kikon *et al*. (2017) evaluated Turmeric cultivation under bamboo-based agroforestry system for the effect of bamboo species and mulch material on weeds and soil characteristics. They revealed that greater weed growth was seen under sole cultivation. The amount of organic carbon (OC), readily available phosphorus (P), and potassium (K) was much higher under bamboo species. In contrast it was discovered that solo farming resulted in higher bulk density (BD), electrical conductivity (EC), and soil pH. It was also observed that in comparison to unmulched plots, mulched plots had higher OC, available nitrogen (N), P, and K levels. The highest values of OC, N, and K were found in T_5 (*Alnusnitida* + FYM + RDF) and the largest amount of accessible P. It was also reported that in T_7 (*Toona ciliata* + FYM + RDF). It was concluded that a turmeric crop grown under sole cropping conditions and supplied with *Pinus roxburghii* mulch, FYM, and RDF results in maximum return.

Onwuka and Uzoma (2018) evaluated the effects of organic mulch materials on soil surface evaporation. The organic mulch materials used were composted and non-composted *Calapogonuim*, *Chromolena* and *Panicum* spp. The application of the mulch materials considerably increased the saturated hydraulic conductivity of the soils. The maximum saturated hydraulic conductivity was found in soil that had non-composted Chromolena spp. mulch applied to it (73.00 cm hr^{-1}). They found that mulch materials from Panicum both composted and uncomposted was more effective physical barrier to stop moisture loss to the atmosphere as compared to other mulch.

Pawar *et al*. (2018) examined the influence of Integrated Use of Manures and Fertilizers on Physico-Chemical Properties of Soil as well as Yield and Cost of Cultivation of Coconut. The application of RDN through FYM at 25 kg/palm/year+ Neem Cake at 15 kg/ palm per year, and Vermicompost at 6 kg / palm / year in three splits is useful for enhancing the physico-chemical characteristics of soil of coconut orchard. The use of RDF + Azadirachtin + Micronutrients through briquettes yields the largest yield, the highest net return, and the best B: C ratio. It was concluded that using Konkan Annapurna Briquettes in three splits to apply RDF, Azadirachtin, and Micronutrients is advantageous for boosting the yield of coconut while maximizing profit.

Shojaei *et al*. (2019) evaluated the optimization of parameters affecting organic mulch test to control erosion. They aimed to produce organic mulch to stop environmental pollution and wind erosion. Mulch materials like straw, blackstrap molasses, manure and biosolids were used. The effects of manure (8-24 g/m^2), biosolids (8-24 g/m^2), and blackstrap (5-15 g/m^2) on wind erosion and penetration were investigated. For straw, manure, blackstrap, and biosolids, the ideal values of crust thickness (1.5 mm) were 12.48, 19.94, 7.16, and 16.70 g, respectively. Straw, manure, blackstrap, and biosolids all had optimal penetration resistance values of 11.31, 15.71, 4.36, and 19.24 g. However, more blackstrap usage had the opposite effect.

Tavali *et al*. (2019) investigated the short-term effects of solid and liquid manure amendments on microbial activity of an alkaline soil with high lime content during horticultural plant growing. It was shown that the combined amounts of solid and liquid manures considerably boosted the quantity of bacteria and the enzyme activity in the soil. It was discovered that the impact of organic fertilizers was more significant than the influence of plant type on the microbial state and activity in soil. As a result of improving soil microbial status and promoting soil microbial activity combined treatments of solid and liquid manures in organic lettuce and rocket growth under greenhouse circumstances definitely increase soil fertility.

Jamir and Dutta (2020) studied the effect of mulching on important soil physico-chemical properties of Khasi mandarin (*Citrus reticulata*) orchard under mid-hill region of Nagaland. It was reported that mulching of plots with organic and inorganic mulch material significantly increased the organic carbon content, available nitrogen, available potassium and available phosphorus in soil when applied along with farm yard manure. Decrease in particle density, bulk density and soil pH was registered.

Goel *et al*. (2020) studied the effect of organic mulches on agronomic parameters–A case study of tomato crop (*Lycopersicon esculentum* Mill.). They reported that the average moisture retained by pine needle mulch, rice straw mulch, wheat straw mulch, and no mulch was 22.18%, 21.01%, 18.52%, and 18.23%, respectively. It was also noted that the mulches reduced soil temperature by 3.3^{o}C in the maximum daily temperature and 1.4-1.8 ^{o}C in the average soil temperature. The beneficial effect on the soil hydrothermal environment resulted directly in enhanced leaf area index, plant height, and yield. It was found that locally accessible organic materials could be employed efficiently to improve production and irrigation water usage efficiency in tomato crops and boost soil moisture retention.

Goel *et al*. (2020) examined the influence of different organic mulches on soil hydrothermal and plant growth parameters in potato crop (*Solanum tuberosum* L.). The field experiment included four mulching treatments: wheat straw mulch, pine needle mulch, rice straw mulch, and no mulch. It was observed that the soil moisture retention increased dependent on the mulch material and depth of the soil layer in the root zone. Mulching also reduced the highest daily soil temperature by 3.5°C, with an average temperature drop of 1-2°Cover the tuber development phase. It was also noted that mulching had a positive impact on root depth, plant height, leaf area index, and tuber yield. It contributed to a yield excess of 1.7-4.4 tonnes ha^{-1} over unmulched conditions, as well as an increase in water use efficiency ranging from 13.5% for rice straw mulch to 34.9% for wheat straw mulch.

Li *et al*. (2020) evaluated the effects of organic mulch on soil moisture and nutrients in Karst Area of Southwest China. The study results showed that straw mulch was extremely important for improving fertility and conserving water. The soil moisture increased as the amount of straw mulch increased. The effect of biochar mulch on soil total nitrogen and total phosphorus reached the maximum, making it significantly higher than that of living mulch. Although soil total organic carbon, total nitrogen, and total phosphorus under the living mulch was lower, the soil tolerant organic carbon was higher under the living mulch. Straw, biochar, and living mulch could improve soil nutrients and moisture conditions to some amount, but only in terms of short-term organic mulch and the low cost and simple availability of mulching materials, and based on the influence of straw mulch on soil moisture and fertility.

Wang *et al*. (2021) investigated the efficient organic mulch thickness for soil and water conservation in urban areas. They revealed that as mulch application increased, soil water content decreased. In comparison to bare soil, mulch applications of 0.25 kg/m^2 and 0.50 kg/m^2 resulted in the highest soil water content and maximum runoff reduction, respectively. Mulch application rates that were higher resulted in reduced soil water content and more runoff. In comparison to bare soil, the amount of runoff and the runoff generation rate decreased by 28-83% and 21-83%, respectively. 56–60% of the total rainfall was absorbed by the soil via soil drainage with a mulch application of 0.25–1.00 kg/m^2. In general, 0.25-0.50 kg/m^2 of mulch was determined to be an effective application rate. It was concluded that research was applicable to dry and semiarid metropolitan areas that get significant rainfall.

Cizkova *et al*. (2021) observed the organic mulch materials improve soil moisture in vineyard. Three type of organic mulch materials were used cereal straw, wood chips and compost. They revealed that the application of three organic components optimized soil moisture. The variant using cereal straw where the highest soil moisture levels were measured produced the best results. The quality of the grapes differed statistically significantly from the control variant when organic mulching materials were used. Author concluded by saying that the agricultural waste can be used to increase soil moisture, and it represents a significant agro-technical intervention in vineyards that helps to safeguard the environment and soils.

Sharma *et al*. (2022) determined the efficacy of various mulch materials and yield of ginger (*Zingiber officinale*) under bamboo-based agroforestry system in NW-Himalaya. The experiment was carried with two bamboo species (*Dendrocalamus asper* and *Bambusa balcooa*) and one in open field. Six types of mulch materials used in the experiment were *Toona ciliate, Artemisia vulgaris, Ulmusvillosa, Celtis* australis and *Pinus roxburghii*. The results showed that production of ginger is better under bamboo-based agroforestry system than sole cropping.

2.4 Bio-economics of Agroforestry

Verma *et al*. (2002) evaluated the economic benefits of agri-horticultural systems and found that the total costs incurred for the Grewia+Almond+Wheat associations were high at 80kg/ha nitrogen (recommended dose) and 100 kg/ha nitrogen (25% higher than the recommended dose), respectively. While net returns showed similar patterns, gross returns were higher in Grewia+Almond+ Wheat than in Morus+ Almond+ Wheat. The highest net returns were generated by sale of Almond fruit. The Grewia +Almond+ Wheat relationship has a net return increase 2.69 times greater than the solidarity wheat crop with a comparable Nitrogen level over the dose that is 25 % higher than the recommended dose. At this nitrogen level, Grewia + Almond + Wheat and single Wheat had cost benefit ratio values of 2.34 and 1.99 respectively.

Hasan *et al*. (2008) carried out a survey in two villages of Durgapur union under Kapasiaupazila of Gazipur district during January to March, 2005 to investigate profitability, problems and management system of practicing jackfruit-pineapple agroforestry practice. The result revealed that the existing jackfruit-pineapple agroforestry system is profitable and has a great contribution to the meet up of nutritional demand. There is a scope of adopting improved management practices and it may increase the total production. Among the various problems, jackfruit trunk borer is the major. The control measures against insects, bat, hedgehog, squirrel etc., use of popular cultivar and training on improved management practices for development of jackfruit-pineapple agroforestry system were suggested to overcome these problems.

Bari and Rahim (2010) evaluated the bio-economic evaluation of Aloe vera in coconut based multistoried agroforestry systems. They revealed that the aloe vera alone produced the highest yield (31.10 t/ha) which was followed coconut and lemon based multi-storied agroforestry. The sisoo+guava multi-story-based agroforestry system had the lowest production (18.53 t/ha). The results indicated that coconut+guava-based multi-storied agroforestry system was followed by coconut+lemon-based multi-storied agroforestry had the highest benefit-cost ratio which was 3.54. In sole cropping the benefit-cost ratio was 1.65 which was the lowest.

Verma and Thakur (2011) evaluated the economic appraisal of Kewach (*Mucuna pruriens*) based agroforestry land-use systems in mid hills of Western Himalayas.Mucuna seeds produced the highest net financial returns when cultivated along with Grewia and Setaria along with Peach and Setaria. Nitrogen application enhanced seed yield. Under the Peach+Setaria+M. pruriens system, Peach and Setaria produced the highest net returns, followed by Peach, Morus, and Setaria. Peach+Setaria+M. pruriens had the highest benefit cost ratio (B: C ratio), followed by Morus+Setaria+M. pruriens. Compared to solo crops, agroforestry systems produced higher net returns. The net returns from intercrop also improved as a result of the nitrogen application, which also increased yield. Fruit-based systems produced larger returns per rupee invested than fodder-based systems did.

Nayak *et al*. (2014) investigated the economics and yield performance of some short duration fruit and medicinal crops under agri-silvicultural system in rain fed uplands of Odisha. They revealed that pineapple registered the maximum fruit yield under mangium and minimum under gamhar. It was also noted that the fresh leave yield of aloevera was maximum under mangium, kalmegh recorded maximum dry plant yield under open condition under gamhar and mangium. Mango-ginger exhibited maximum rhizome yield under open condition followed by gamhar and mangium. It was concluded by author that pineapple based agri-silvicultural system recorded the highest gross return, net return and BCR as compared to other agri-silvicultural systems and sole crops.

Kassa (2015) analyzed the profitability analysis and determinants of fruit tree-based agroforestry system in Wondo District, Ethiopia. Fruit trees-based agroforestry is more environmentally friendly, has higher adoption rates and financial benefits. This study looked into what makes fruit-tree based agroforestry successful and it was noted that the crops grown in land use, produced the largest economic profit. It is a more economically beneficial, labour-saving, and less hazardous investment with diverse income sources than monocropping systems

Pandey *et al*. (2016) studied the economic comparison of intercropping of ginger and turmeric under sapota-jatropha based agro-forestry systems in south Gujarat. They revealed that intercropping ginger with Sapota + Jatropha or Jatropha based agro-forestry systems resulted in a much higher B: C ratio than sole cropping or intercropping under Sapota, whereas intercropping turmeric with Sapota or Sapota + Jatropha agro-forestry systems resulted in a much lower B: C ratio than sole cropping or intercropping under Jatropha. The economic study concludes that the net revenue and BCR are higher for turmeric than for ginger; net cost of production is higher for ginger.

Bhusara *et al*. (2016) evaluated the bio-economic appraisal of traditional agroforestry systems prevalent in valsad district of Gujarat. It was noted that the economic yield of mango was measured to be 15, 14.82, and 6.57 tonnes/ha under agri-horticulture (Mango + banana), horti-pasture (Mango + sorghum), and Mango + maize systems, respectively. The two horti-pasture system types, mango + maize and mango + sorghum, produced the maximum economic yields of maize and sorghum (55.36 t/ha) and sugarcane (55.36 t/ha) under the teak + sugarcane agri-silviculture system. The teak + sugarcane system produced the highest overall economic yield (55.36 t/ha), followed by the mango + sorghum and mango + banana systems with values of 39.07 and 33.72 t/ha, respectively. Mango + Banana system type had the highest overall net returns of 6, 96, 678 /ha followed by Mango + Sorghum system type with net returns of 5, 95, 717 /ha. The Mango fruit yield under Mango + Banana had the highest net returns from the woody component, which includes Teak and Mango in various tree crop combinations.

Singh and Manvi (2016) investigated the economic analysis of Poplar based agroforestry system under Riparian Wetland conditions of Punjab. Five villages were selected for the research. It was seen that most of the farmers used spacing but a fraction used spacing. The cost and revenue analysis of the poplar and in crop plantations revealed a B:C ratio 2.87, an internal rate of return of 57.50 percent, and a net present worth of 12,28,162 hectares, demonstrating the viability of Poplar based agroforestry in the study area. Large Poplar plantations tended by medium and small farmers were shown to have a better B:C ratio of return and net percent worth.

Anshiso *et al*. (2017) studied the financial analysis of fruit tree-based agroforestry Practice in Hadero Tunto Zuria Woreda, Kembata Tembaro Zone, and South Ethiopia. They revealed that the widespread nature of the fruit tree-based agroforestry system is in the research area. Agroforestry practices based on fruit trees are not only economically viable than monocropping systems but they are also less susceptible to variations in price, yield, and discount rate. Fruit based agroforestry are often preferable to monocropping systems because they offer greater economic and environmental advantages and have fewer risky characteristics.

Kaler and Pant (2017) analysed the economic analysis of existing agroforestry systems in different altitudinal zones of Kangra valley of Himachal Pradesh, India. The study found that three agroforestry system agri-silviculture (AS), agri-silvi-horticulture (ASH) and agri-horticulture (AH) were more common among different types of farmers in three altitudinal zones. The bio-economics of the systems were calculated using the cost of cultivation, gross return per hectare, net return per hectare, and benefit-cost ratio.

Kaler and Pant (2017) Evaluated the economic analysis of pastoral agroforestry systems in different altitudinal zones of Kangra valley in Himachal Pradesh, India. The study revealed that the farmers in three altitudinal zones preferred to use one of three types of pastoral agroforestry systems: agri-silvi-pastoral, silvi-pastoral, or pastoral-silviculture. The benefit-cost ratio, gross return on investment per hectare, net return on investment per hectare, and cost of cultivation were all calculated to analyse the bio-economics of the systems.

Mali *et al*. (2017) studied the economic evaluation of sugarcane-based agroforestry systems. The study was taken up to analyse the tangible and intangible benefits derived from traditional sugarcane-based agroforestry system followed by farmers. Tree species like *Tectona grandis*, *Gmelina arborea*, *Eucalyptus spp*., *Casuarina equisetifolia* and *Leucaena leucocephala* are dominant species in traditional agroforestry system (AFS). Teak-sugarcane based agroforestry gave highest B: C ratio of 3.9, followed by *G. arborea* (1.6). Whereas, *Eucalyptus*; *C. equisetifolia*; *L. Leucocephala*-sugarcane systems the benefit-cost ratio was 1.4, 1.3 and 1.3, respectively which is nearly equivalent to the B: C ratio for sugarcane sole cultivation. It was found that sugarcane based AS becomes more profitable especially when it is surrounded by the *T. grands* and *G. arborea* as compared to sugarcane alone, *Eucalyptus, C. equisetifolia and L. leucocephala*.

Kaur *et al*. (2017) estimated the productivity and profitability of intercrops under four tree species throughout their rotation in north-western India. It was noted that Fresh stem biomass was lowest in toon and highest in eucalypt. The growth of the trees increased each successive year, the growth and yield of all crops under tree plantations decreased. The toon plantation had the least negative impact on understorey crops, while eucalyptus produced the greatest yield drop of all the intercrops. It was seen that Turmeric and wheat produced more when cultivated as intercrops. The intercropping of turmeric with poplar and eucalyptus produced the highest net returns among the various tree-crop combinations, followed by poplar and wheat. It was also observed that the soil fertility condition was also increased through agroforestry systems and the Melia and poplar-based agroforestry systems respectively the available N and P were at their maximum levels.

Adane *et al*. (2019) examined the contribution of a fruit tree-based agroforestry system for household income to smallholder farmers in Dale District, Sidama Zone, and Southern Ethiopia. The study revealed that the fruit tree-based agroforestry system contributes number of products. It was also seen that financial analysis showed that the fruit tree-based agroforestry practice was more profitable than mono cropping.

Jilariya *et al*. (2019) examined the economics of cultivation of *Melia dubia* Cav.-*Aloe Vera* L. silvi-medicinal model. The value addition due to pulp production provided higher net returns and BCR under all the systems. The net present value (NPV), internal rate of returns payback period and BCR analysis expressed that among *M. dubia-Aloe vera* silvi-medicinal and sole cropping systems (either *A. vera or M. dubia*), the most economically viable systems could be *M. dubia* (2m×2 m) + *A. vera* system. The economic analysis underpinned that NPV, IRR, PBP and BCR values are lesser on raw product (fresh *A. vera* leaf) production compared to pulp production.

Dutt and Thakur (2020) investigated the bio-economics of cropping systems combining medicinal and aromatic herbs with commercial timber tree species. They indicated that net returns were generally higher under agroforestry systems that included poplar and *Tagetes minuta* at various spacing than monocropping. It was also noted that the net returns from sole cropping were higher in the case of *Spi/anthesacmella* than they were from agroforestry intervention. The net returns from *Withania somnifera* were unfavourable when the crop was grown pure or intercropped with poplars. the system generated a significant amount of income when *Withania somnifera* and poplar were combined at various spacings. Author revealed that combination can yield significantly greater net returns because of the superior performance of 8m x 3 m and 6m x 4 m spacings over 5m x 5 m and 4m x 6 m spacings.

Nworji (2020) evaluated bioeconomic potential for silvo-pastoral agroforestry system in north wales. This study also showed that the increase in lamb sale price, wood price, and wood yield improved the economic feasibility of the three investments greatly. Agroforestry, pasture/livestock, and forestry were the next most viable options, with the highest NPV. The results of this study will contribute in raising the awareness of the economic importance of trees in heavily grazed landscapes in the UK and serving as a foundation for comparisons and analyses of agricultural programs and ecosystem service markets in the future.

Pratap *et al*. (2020) analysed the economic feasibility of *Melia composita*-radish based agri-silviculture systems. The results showed that intercropping radish with M. composita at a spacing of 8 m×5 m contributed the highest net returns. It suggests that agrisilviculture system based on *M. composita* and radish may deliver superior economic returns than a sole cropping system. The IRR and BCR analyses confirmed that intercropping *M. composita* with radish at a wider spacing (8 m ×5 m) might be the most economically efficient system.

Amin *et al*. (2021) investigated the bio-economic performance of organic cucumber (*Cucumis Sativus L*.) under woodlots-based agroforestry systems. The results revealed that the highest cucumber fruit yield (9.15 tons/ha) was observed by growing under *Albizia lebbeck* with dry water hyacinth mulch. It was noted that the benefit-cost ratio (BCR) was the highest (2.89) in cucumber under *Albizia lebbeck* woodlot agroforestry. It was concluded that cucumber grown under *Albizia lebbeck* woodlot agroforestry with dry water hyacinth mulch can be a cost-effective production practice for securing higher yields.

Rahmana *et al*. (2021) analysed the performance of winter vegetables cultivation in mango fruit-tree based agroforestry System. The yield of radish equivalents, gross return, net return, and BCR were all significantly higher in radish cultivation. The performance that was most detrimental was the cultivation of mustard leaves. It was clear that radish farming in agroforestry systems was more economical than growing other winter crops. So, radish farming could be promoted in agroforestry system based on mango trees.

Thakur *et al*. (2022) evaluated the bio-economic appraisal of *Phaseolus Vulgaris* Under *Morus Alba*-Based Agri-Silvicultural System. The results indicated that *Phaseolus vulgaris* can be cultivated successfully in an agroforestry system when a lopping intensity of 75% was used along with an acceptable rate of combined dosages of RDF and FYM. It was not only beneficial for enhancing the productivity of the vegetable crop but also proved to be economically more viable as compared to the application of other treatments.

Chapter-3

MATERIALS AND METHODS

The present investigation entitled **"Effect of different farming practices and mulches on production of strawberry under wild pomegranate-based agroforestry systems"** was carried out in the Experimental farm Pandah of Department of Silviculture and Agroforestry, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, during the years 2022-23. The details of materials used and methodologies employed to execute the studies have been described below:

3.1 EXPERIMENTAL SITE

3.1.1 Location

The experiment was laid out at an elevation of 1200 m above mean sea level at 30° 51'N latitude and 76° 11'E longitude in the experimental farm Pandah of the Department of Silviculture and Agroforestry, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh.

3.1.2 Climate

The experimental site lies under the mid hills sub humid zone-II agro climatic zone of Himachal Pradesh where, summer is moderately hot during May-June while, winter is quite severe during December-January. The annual rainfall ranges from 110-120 cm, major amount of which is received from mid-June to September. The mean annual minimum and maximum temperature are recorded as 14ºC and 25ºC respectively. The minimum and maximum temperature varies from 3ºC during winter to 33ºC during summer. The meteorological data pertaining to the period of research work is given in Table 1.

Table 1. Mean monthly data of Dr Y S Parmar University of Horticulture and forestry, Nauni, Solan (HP) for the period October–April, 2022-23

Month	Temperature (ºC)		Relative Humidity (%)	Rainfall (mm)
	Max (ºC)	Min (ºC)		
October, 2022	26.29	11.41	64.08	2.57
November, 2022	24.07	6.41	55.15	0.08
December, 2022	21.68	2.53	51.03	0.00
January, 2023	18.75	2.85	61.24	1.26
February, 2023	23.78	5.56	52.43	0.26
March, 2023	23.57	8.05	63.77	4.21
April, 2023	26.63	10.51	51.40	3.81

Source: Meteorological observatory, Department of Environment Science, College of Forestry, Dr Y S Parmar University of Horticulture and forestry, Nauni, Solan (HP).

3.1.3 Physico-chemical properties of soil before the experiment

The physico-chemical properties of soil were determined before conducting the experiment, the nutrient status of soil and other detailed information is presented in Table 2.

Table 2. Physico-chemical properties of experimental field before sowing

Sr. No.	Soil parameters	Canopy	Open
1	Soil pH (1:2)	6.49	6.66
2	EC (dS m^{-1})	0.31	0.21
3	Organic carbon (%)	0.69	0.62
4	Soil moisture (%)	8.28	7.84
5	Available N (Kg ha^{-1})	325.18	308.21
6	Available P (Kg ha^{-1})	51.53	49.20
7	Available K (Kg ha^{-1})	239.99	234.48

3.2 EXPERIMENTAL DETAILS

The present investigations entitled "Effect of different farming practices and mulches in production of strawberry under wild pomegranate-based agroforestry systems" was carried out at Experimental farm Pandah of Department of Silviculture and Agroforestry, College of Forestry, UHF Nauni, Solan. The detail of experimental is as under:

3.2.1. Structural components

Tree : ***Punica granatum***

Spacing : 4×2 m^2

Year of planting : 2020

Field crop : **Strawberry *var.* Camarosa**

Date of Transplanting: 1^{st} week of October, 2022

Spacing R×R : 60×60 cm^2

Spacing P×P : 30×30 cm^2

Experimental design : RBD

Treatment details:

T_1 : Control

T_2 : Bamboo mulch alone

T_3 : Bamboo mulch + Natural farming

T_4 : Bamboo mulch+ RDF

Plate 1. Start of Experiment

Plate 2. Strawberry under Wild pomegranate based Agroforestry System

T_5 : Bamboo mulch+ FYM

T_6 : Pine mulch alone

T_7 : Pine mulch+ Natural farming

T_8 : Pine mulch+ RDF

T_9 : Pine mulch+ FYM

T_{10} : Poplar mulch alone

T_{11} : Poplar mulch + Natural farming

T_{12} : Poplar mulch+ RDF

T_{13} : Poplar mulch+ FYM

1. Planting conditions = 2

i) Open field

ii) Under wild pomegranate canopy

2. Farming practices = 4

i) RDF

ii) NF

iii) FYM

iv) Control

3. Mulches = 3

i) *Pinus roxburghii*

ii) *Bamboo spp.*

iii) *Poplar deltoids*

Treatment combinations : 2×4×3=24

Replications : 3

Plot size : 3×2 m^2

Total number of plots : 2 ×4(Fertilizer) ×3(Mulches)× 3=72

3.2.2 Field preparation

The experiment field was thoroughly ploughed with the help of tractor followed by planking before sowing. Stones, pebbles were removed from field manually, the field was well levelled and sufficient provision for proper drainage was kept.

3.3.3 Application of manures

Well rotten farm yard manure (FYM:50 tonnes/ha) was applied. N, P, K were applied in the form of calcium ammonium nitrate (CAN:80kg), single super phosphate (SSP:40kg) and muriate of potash (MOP:40kg), respectively.

3.3.4 Transplantation of strawberry

Transplantation of the runners was done in the 1^{st} week of October 2022 after transplanting light irrigation was applied. Runners were transplanted at the spacing of 30cm line to line and 20cm plant to plant.

3.3.5 After care

The experimental site was visited regularly. Weeding was carried out during the crop growth period to ensure healthy crop stands. Irrigation was applied when required.

3.3.6 Crop Protection

No major diseases or attack of insect pest was observed during the course of investigation'. The effect of hail was observed and to prevent further damages fungicides was sprayed. Field was covered from all sides and from top to prevent the crop from the attack of birds, rabbits and other animals.

3.4 OBSERVATIONS RECORDED

During the course of investigations, observations on growth, flowering, and fruit quality and physico-chemical properties of soil were recorded, as per the details given below:

3.4.1 Tree species: Wild Pomegranate Parameters

The tree parameters viz. heights, crown spread, photosynthetically active radiation, fruit yield per tree of wild pomegranate were recorded at the end of experiment.

3.4.1.1 Tree height (m)

Height of wild pomegranate was measured with the help of wooden shaft.

3.4.1.2 Crown spread (m)

The crown spread (m) was measured in two directions viz; North-South and East-West. The average of the two was taken as crown spread.

$$CS = \frac{D1+D2}{2}$$

Where;

CS	=	Crown spread
D_1	=	Crown spread in N-S direction (m)
D_2	=	Crown spread in E-W direction (m)

3.4.1.3 Fruit yield per tree (Kg/plant)

The total fruit harvested tree^{-1} was weighed and expressed as fruit yield kg tree^{-1}.

3.4.1.4 Light transmission ratio (%)

LTR was measured using Lux meter in every 15 days.

3.4.1.5 Photo-synthetically Active Radiation (µmol m^{-2} s^{-1})

PAR was measured using ACCUPAR LP-80 Ceptometer.

3.4.2 Field Crop: Strawberry

3.4.2.1 Growth Parameter

3.4.2.1.1 Plant height (cm)

The height of plants was measured with a measuring scale from the crown level to the apex of primary leaves and the trait was expressed in centimetres (cm).

3.4.2.1.2 Plant spread (cm)

Plant spread was measured in both the directions i.e., East-West (E-W) and North-South (N-S) and the mean was taken as the actual plant spread.

3.4.2.1.3 Leaf area (cm^2)

The leaf area was recorded with the help of the leaf area meter (LI-COR 3100). Five samples from each replication were taken for measuring leaf area.

3.4.2.1.4 Number of leaves per plant

The total number of leaves was recorded from randomly selected five plants at the end of harvest and the average value was expressed as leaf number per plant.

3.4.2.1.5 Total chlorophyll content (SPAD)

A sample of five representative fully grown leaves from the experimental plant were selected and each was tested using SPAD-502 Plus.

3.4.2.2 Cropping parameter

3.4.2.2.1 Number of flowers per plant

Five plants in each replication were tagged and the number of flowers per plant for each treatment was counted and the results were expressed as number of flowers per plant.

3.4.2.2.2 Fruit set

Five plants tagged for recording the observation on total number of flowers were used to record the data on fruit set. Total numbers of flowers were counted in each plant and twenty days after flowering the number of fruits were also counted. The per cent fruit set per plant was calculated by using formula.

$$\text{Fruit set} = \frac{total\ number\ of\ fruit}{total\ number\ of\ flowers} \times 100$$

3.4.2.2.3 Number of fruits per plant

The number of fruits was counted per plant at the time of fruit maturity and was expressed as number of fruits per plant.

3.4.2.2.4 Yield per plant

The weight of entire fruits harvested per plant was recorded for each treatment and the result was expressed as yield in gram per plant.

3.4.2.2.5 Yield per hectare

The weight of entire fruits harvested from each plot was recorded for each treatment. The yield per hectare was worked out and expressed as tons per hectare.

3.4.2.3 Fruit quality parameter

3.4.2.3.1 Fruit length (mm)

The length of five randomly selected fruits in each harvest was measured with the help of measuring scale and the values were expressed in millimetres (mm).

3.4.2.3.2 Fruit diameter (mm)

The diameter of five randomly selected fruits in each harvest was measured with the help of digital Vernier calliper and the values were expressed in millimetres (mm).

3.4.2.3.3 Fruit weight (g)

Five randomly selected fruits from each harvest, used for measuring the fruit weight were weighed on a top-pan electrical balance and the average weight of berry was calculated and expressed in gram (g).

3.4.2.4 Bio-chemical parameters

3.4.2.4.1 Total soluble solids

The total soluble solids of the fruit juice were determined with the help of Erma-Hand refractometer (0 to 32°B). The refractometer was calibrated with distilled water before use. The readings were recorded for each sample by putting a drop of juice on the prism (AOAC, 1980). A temperature correction was applied when it was above or below 20°C and the readings were expressed in degree Brix (°B).

3.4.2.4.2 Titratable acidity

Ten grams of fruit pulp was taken, homogenised with distilled water in an electric blender and volume made to 250 ml. The mixture was then filtered through Whatman No.1 filter paper. Twenty-five millilitres of this extract were titrated against 0.1 N NaOH solution using phenolphthalein as an indicator till it gave pink coloured end point. The total titratable acidity was calculated in terms of malic acid on the basis of one ml of 0.1 N NaOH equivalents to 0.0067 g of anhydrous malic acid. The results were then expressed in terms of percentage with the following formula (Ranganna, 1995).

$$\text{Titratable acidity (\% malic acid)} = \frac{\text{Titre value} \times \text{Normality of Alkali} \times \text{Volume made up} \times \text{Equivalent weight of acid} \times 100}{\text{Volume of sample taken for estimation} \times \text{Volume of aliquot taken} \times 1000}$$

3.4.2.4.3 TSS/acid ratio

The ratio was obtained by dividing the corresponding value of total soluble solids to the malic acid content of the fruit juice.

3.3.4.4 Sugars

For the estimation of sugars, ten grams of fruit pulp was thoroughly homogenised with distilled water in an electric blender and volume made to 250 ml in volumetric flask and filtered through Whatman No. 4 filter paper and the final volume was made to 250 ml with distilled water in a volumetric flask. This was then neutralized with 1N NaOH. Five millilitres of lead acetate (45 %) were added to it and kept for 10 minutes to remove the impurities. Excess of lead acetate was removed from the sample by using a sufficient quantity of potassium oxalate (22 %). Again, the volume was made to 250 ml with distilled water and filtered through Whatman No.4 filter paper. From this clear filtrate, 50 ml was separated for the estimation of total sugar and rest was used for estimation reducing sugars as below.

3.4.2.4.4 Total Sugars

For the estimation of total sugar, already separated 50 ml diluted and clarified solution was hydrolysed by adding 5 ml of concentrated hydrochloric acid and leaving it overnight. The excess of hydrochloric acid was neutralized by 10 per cent sodium hydroxide solution and the final volume was made to 250 ml with distilled water (aliquot). The total sugar was estimated by titrating a boiling mixture of 5 ml each of Fehling A and B solutions against aliquot using methylene blue as an indicator. The end point was noted upon obtaining brick red colour and total sugar was expressed as percentage of fresh weight of fruit pulp and calculated as per formula given below (Ranganna, 1995).

$$\text{Total sugars (\%)} = \frac{Factor \times Dilution \times Dilution}{Titre\ value \times weight\ or\ volume\ of\ sample\ taken} \times 100$$

* Factor = 0.05

3.4.2.4.5 Reducing sugars

For estimation of reducing sugar, 5 ml of each Fehling solution A and Fehling solution B was taken in a beaker and 50 ml of distilled water was added to it. It was then boiled for about 10 minutes and then 2-3 drops of Methylene blue indicator were added and titrated against filtrate obtained. The beaker was regularly shaken and the end point of filtrate used was noted by obtaining a brick red colour. Reducing sugars were estimated as per cent and calculated as per formula given below:

$$\text{Reducing sugars (\%)} = \frac{Factor \times Dilution \times Dilution}{Titre\ value \times weight\ or\ volume\ of\ sample\ taken} \times 100$$

* Factor = 0.05

3.4.2.4.6 Non-reducing sugars

The percentage of non-reducing sugars in the juice was determined by subtracting the reducing sugars from the total sugars and multiplying the difference by the standard factor 0.95. The results were expressed as percentage of juice weight.

Non-reducing sugar (%) = (Total sugars – Reducing sugars) x 0.95

3.4.2.4.7 Anthocyanin content

Anthocyanin pigment in berry skin was determined by the method given by Harborne (1973). One gram of berry pulp was macerated in a known quantity of methanol containing 1 per cent hydrochloric acid. The content was kept to overnight at 0°C temperature in a deep freezer. The absorbance of red coloured solution was recorded at 530 nm on Spectronic-20 colorimeter. Anthocyanin content was expressed as absorption units at 530 nm per gram fresh berry.

3.4.3 Physico-chemical properties of soil

3.4.3.1 Soil pH

Soil pH was measured using digital pH meter by making 1:2 soil-water suspensions (Jackson, 1973).

3.4.3.2 Electrical conductivity (dS m^{-1})

EC was determined using the same suspension prepared for pH determination, using Electrical conductivity meter (Jackson, 1973).

3.4.3.3 Organic carbon (%)

Soil organic carbon was analysed with the help of a rapid titration method (Walkley and Black, 1934).

3.4.3.4 Available N (kg ha^{-1})

Available nitrogen was measured by the Alkaline potassium permanganate method (Subbiah and Asija, 1956).

3.4.3.5 Available P (kg ha^{-1})

Available phosphorus was measured with the help of Olsen method (Olsen *et al*., 1954).

3.4.3.6 Available K (kg ha^{-1})

Available potassium was determined by the Merwin and Peech method (Merwin and Peech, 1951).

3.4.3.7 Soil moisture (%)

The soil samples were collected from each plot. The samples were collected using auger and dried at 105ºC till constant weight achieved.

Soil moisture content was calculated as under:

$$\text{Soil moisture (\%)} = \frac{\text{Fresh weight} - \text{dry weight}}{\textit{Fresh weight}} \times 100$$

3.4.4 Bio-economic analysis

Economic appraisal of different treatments (tree-crop combinations and sole crops) was done for comparison and selecting the best combination for recommendation to stakeholders Productivity of the sole crops and tree-crop combinations was subjected to economic analysis by calculating cost of cultivation, gross and net returns per hectare. All these parameters were calculated on the basis of prevailing market prices at the time of termination of the experiment

3.4.4.1. Cost of cultivation (Rs/ha)

The cost of cultivation of component of agroforestry i.e., field crop and tree component were worked out on the basis of net cropped area per hectare. The requirements of labour and mechanical power for different operations such as ploughing, harrowing, weeding and harvesting were calculated as per the prevalent rate. Farm Cost of inputs such as seeds.

farm yard manure fertilizers and pesticides were calculated based on the actual amounts applied to different crops Similarly, cost of cultivation of trees (*Punica granatum* L.) including harvest of their fruits was computed with respect to variable cost involved in maintenance and harvesting of fruits on per hectare basis during the year of the study

3.4.4.2. Gross returns (Rs/ha)

The prevailing local market prices were used to convert yield of fruit crop and fruits of *Punica granatum* L. into gross returns per hectare. Gross returns were obtained by multiplying the quantity of produce with the prevailing prices in the market.

3.4.4.3. Net returns (Rs/ha)

Net returns were calculated by subtracting the cost of cultivation from the gross returns.

Net returns ha^{-1}= Gross returns ha^{-1} – Cost of cultivation ha^{-1}

3.4.4.4. B:C Ratio

Ratio of the gross returns per rupee invested was calculated as per following formula:

$$\textbf{B:C} = \frac{Gross\ returns\ (Rs/ha)}{Cost\ of\ cultivation\ (Rs/ha)}$$

3.5 STATISTICAL ANALYSIS

The data was be subjected to analysis of variance (RBD) two factorial by using statistical package R (Version 3.4.0).

Chapter-4

RESULTS AND DISCUSSION

The present investigation entitled **"Effect of different farming practices and mulches on production of strawberry under wild pomegranate-based agroforestry systems"** was carried out at the experimental farm Pandah of Department of Silviculture and Agroforestry, Dr YS Parmar University of Horticulture and of Forestry, Nauni, Solan, Himachal Pradesh, during the year 2022-2023. The main aim of the study was to analyze the effect of different manures and mulches on vegetative, cropping, quality, biological traits of strawberry. The results obtained during the period of investigation are presented here under the following heads and subheads:

4.1 Growth characteristics of wild pomegranate

- **4.1.1 Tree height (m)**
- **4.1.2 Crown spread (m)**
- **4.1.3 Light transmission ratio (%)**
- **4.1.4 Fruit yield per tree (Kg)**
- **4.1.5 Photo-synthetically active radiation (µmol m^{-2} s^{-1})**

4.2 Field crop

- **4.2.1 Growth Parameter of *Fragaria*× *ananassa* Duch.**
  - **4.2.1.1 Plant height (cm)**
  - **4.2.1.2 Plant spread (cm)**
  - **4.2.1.3 Leaf area (cm^2)**
  - **4.2.1.4 Number of leaves per plant**
  - **4.2.1.5 Total chlorophyll content (SPAD)**
- **4.2.2 Cropping parameter of *Fragaria*× *ananassa* Duch.**
  - **4.2.2.1 Number of flowers per plant:**
  - **4.2.2.2 Fruit set (%)**
  - **4.2.2.3 Number of fruits per plant**
  - **4.2.2.4 Yield per plant (g)**
  - **4.2.2.5 Yield per hectare (ton ha^{-1})**
- **4.2.3 Fruit quality parameter of *Fragaria*× *ananassa* Duch.**
  - **4.2.3.1 Fruit length (mm)**

4.2.3.2 Fruit diameter (mm)

4.2.3.3 Fruit weight (g)

4.2.4 Bio-chemical quality parameter of *Fragaria× ananassa* Duch.

4.2.4.1 Total soluble solids (ºB)

4.2.4.2 Titratable acidity (%)

4.2.4.3 TSS: acid ratio

4.2.4.4 Total sugar (%)

4.2.4.5 Reducing sugar (%)

4.2.4.6 Non-reducing sugar (%)

4.2.4.7 Anthocyanin content (%)

4.3 Physico-chemical properties of soil under agroforestry system

4.4 Change in physico-chemical properties of soil under agroforestry system

4.5 Correlation between growth, yield and soil parameters

4.6 Bio-Economic analysis

4.1 GROWTH CHARACTERISTICS OF WILD POMEGRANATE

The data for the growth characteristics of wild pomegranate is given in Table 3.

4.1.1 Tree height (m)

The average height of *Punica granatum* tree was 2.80 m, represented in Table 3.

4.1.2 Crown spread (m)

The average crown spread of *Punica granatum* tree was 1.90 m.

4.1.3 Fruit yield per tree (Kg)

The average fruit yield per tree of *Punica granatum* was 4.00 kg.

4.1.4 Light transmission ratio (%)

The average light transmission ratio under *Punica granatum* tree was 9729.67 lux.

4.1.5 Photo-synthetically active radiation (PAR)

The average photo-synthetically active radiation under *Punica granatum* tree was 433.86 µmol m^{-2} s^{-1}.

Table 3 Tree characteristics under wild pomegranate-based agroforestry system

Parameter	Height (m)	Crown spread (m)	Fruit yield/tree (kg)	LTR 100	PAR (µ mol m^2 s^{-1})
Mean	2.80 m	1.90 m	4.00 Kg/tree	9729.67 lux	433.86

* PAR in open field (520.11 µ mol m^2 s^{-1})
*Light Transmission Ratio in open 17166.45 lux

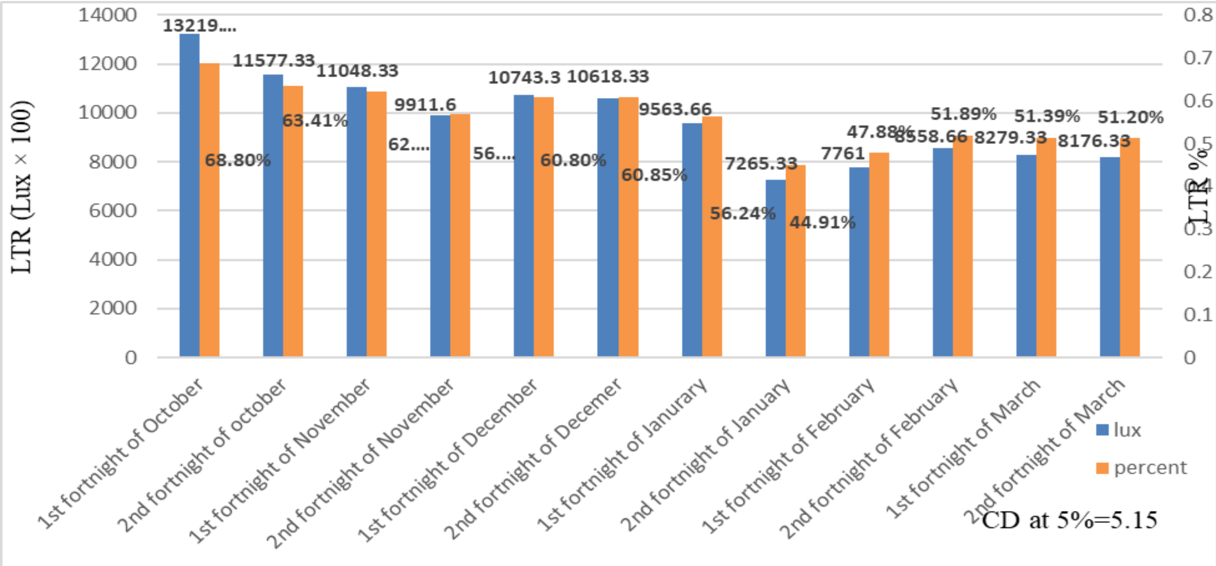

Fig 1. Average LTR over different period of time

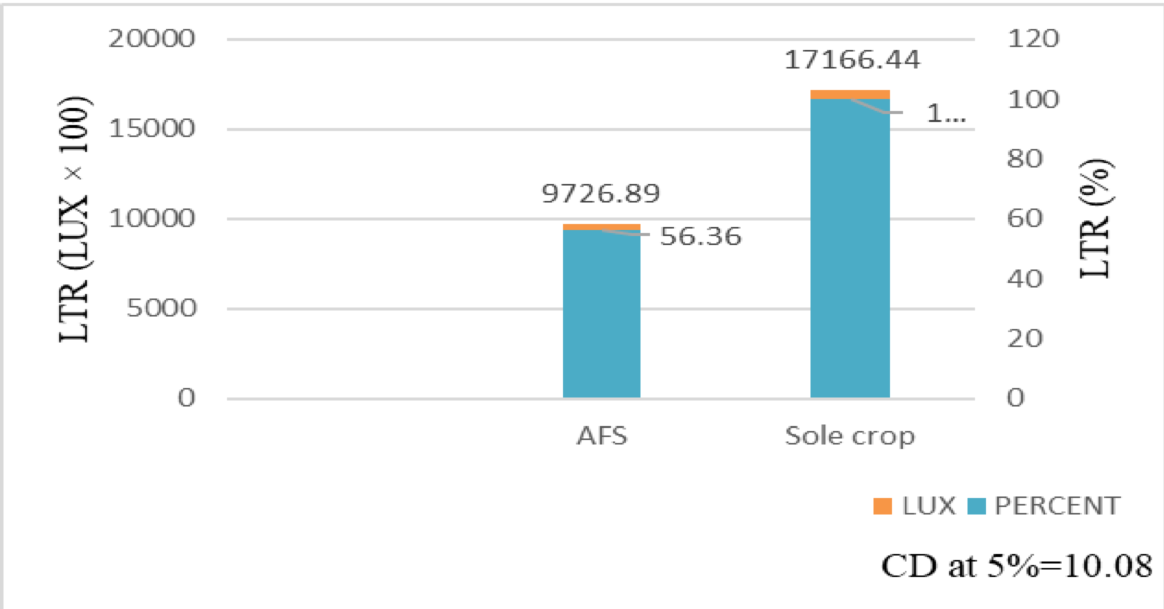

Fig 2. Average LTR under different planting condition

4.2 FRUIT CROP

4.2.1 Growth parameter of *Fragaria*× *ananassa* Duch.

4.2.1.1 Plant height (cm)

The data regarding the effect of mulches and manures on plant height (cm) of strawberry under wild pomegranate-based agroforestry system had been recorded and presented in Table 4.

Table 4. Effect of different mulch and manures on plant height (cm) of strawberry under wild pomegranate-based agroforestry system

Planting condition / Treatment	Plant height (cm)		
	S_1 (Canopy)	S_2 (Open)	Mean
T_1 (Control)	9.87	7.04	**8.45^{g}**
T_2 (Bamboo mulch alone)	11.32	8.66	**9.99^{cde}**
T_3 (Bamboo mulch + Natural farming)	11.31	8.12	**9.71^{def}**
T_4 (Bamboo mulch+ RDF)	11.66	7.94	**9.80^{cdef}**
T_5 (Bamboo mulch+ FYM)	10.58	8.36	**9.47^{ef}**
T_6 (Pine mulch alone)	11.88	7.81	**9.85^{cdef}**
T_7 (Pine mulch+ Natural farming)	12.21	7.88	**10.05^{bcde}**
T_8 (Pine mulch+ RDF)	12.82	7.42	**10.12^{bcd}**
T_9 (Pine mulch+ FYM)	12.34	8.26	**10.30^{bcd}**
T_{10} (Poplar mulch alone)	10.82	7.69	**9.26^{f}**
T_{11} (Poplar mulch + Natural farming)	13.54	7.76	**10.65^{ab}**
T_{12} (Poplar mulch+ RDF)	12.83	8.02	**10.43^{abc}**
T_{13} (Poplar mulch+ FYM)	13.67	8.37	**11.02^{a}**
Mean	**11.91^{x}**	**7.94^{y}**	
$CD_{(0.05)}$ **T** 0.64 **S** 0.25 **T × S** 0.91			

The perusal of data presented in Table 4 revealed that different treatments planting conditions exerted significant effect on plant height of strawberry under wild pomegranate-based agroforestry system. Among different manures and mulches maximum (11.02 cm) plant height was recorded in treatment T_{13}, which was statistically at par with T_{11}, T_{12} and minimum plant height (8.45 cm) was recorded in treatment T_1 (control).

Whereas effect of plant condition on plant height, as maximum plant height (11.91 cm) was recorded under S_1 (agroforestry system) and the minimum plant height (7.94 cm) was recorded under S_2 (open condition).

The combined effect of planting condition and treatments (T×S) showed significant effect on plant height. Maximum plant height (13.67 cm) was recorded in treatment combination $T_{13}S_1$ which was statistically at par with the treatment combination $T_{12}S_1$ and T_8S_1 and minimum (7.04 cm) was recorded in T_1S_2.

4.2.1.2 Plant spread (cm)

The observations regarding the effect of planting conditions on plant spread (cm) of strawberry under wild pomegranate-based agroforestry system had been recorded and presented in Table 5.

Table 5. Effect of different mulch and manures on plant spread (cm) of strawberry under pomegranate-based agroforestry system

Treatment / Planting condition	Plant spread (cm)		
	S_1 (Canopy)	S_2 (Open)	Mean
T_1(control)	20.60	10.46	**15.53^{f}**
T_2(Bamboo mulch alone)	25.89	12.58	**19.23^{ab}**
T_3(Bamboo mulch + Natural farming)	22.01	11.33	**16.67^{ef}**
T_4(Bamboo mulch+ RDF)	23.28	13.22	**18.25^{bcd}**
T_5(Bamboo mulch+ FYM)	23.61	11.33	**17.47^{cde}**
T_6(Pine mulch alone)	22.28	14.09	**18.18^{bcde}**
T_7(Pine mulch+ Natural farming)	22.48	12.83	**17.65^{cde}**
T_8(Pine mulch+ RDF)	26.74	13.83	**20.28^{a}**
T_9(Pine mulch+ FYM)	22.93	13.63	**18.28^{bcd}**
T_{10}(Poplar mulch alone)	21.16	13.33	**17.24^{de}**
T_{11}(Poplar mulch + Natural farming)	22.92	13.50	**18.21^{bcde}**
T_{12}(Poplar mulch+ RDF)	26.17	14.04	**20.10^{a}**
T_{13}(Poplar mulch+ FYM)	25.80	12.21	**19.01^{abc}**
Mean	**23.53^{x}**	**12.80^{y}**	
$CD_{(0.05)}$ **T** 1.58 **S** 0.62 **T × S** 2.23			

It is evident from the data that different treatments have significant effect on plant spread of strawberry under wild pomegranate-based agroforestry system. The maximum (20.28 cm) plant spread was recorded in treatment T_8 (*Pinus roxburhii* + RDF), which was statistically at similar with T_{12}, T_2, T_{13}. Minimum plant spread (15.53 cm) was recorded in treatment T_1 (control).

The planting condition had significant effect on plant spread, as maximum plant spread (23.53 cm) was recorded under S_1 (agroforestry system) and the minimum plant height (12.80 cm) was recorded under S_2 (open condition).

The combined effect of planting condition and treatment (T×S) showed significant effect on plant spread. Maximum plant spread (26.74 cm) was recorded in treatment combination T_8S_1, which was statistically at par with the treatment combination $T_{12}S_1$, T_2S_1 and $T_{13}S_1$ and minimum (10.46 cm) was recorded T_1S_2.

4.2.1.3 Leaf area (cm^2)

Data recorded and presented in Table 6, depicted the effect of mulches and manures on leaf area of strawberry under wild pomegranate-based agroforestry system.

It can be deduced from the data represented in Table 6 that different treatments exerted non-significant effect on leaf area of strawberry under wild pomegranate-based agroforestry system.

The planting conditions had significant effect on leaf area, as maximum leaf area (42.73 cm^2) was recorded under S_1 (agroforestry system) and the minimum leaf area (16.94 cm^2) was recorded under S_2 (open condition).

The combined effect of planting condition and treatment (T×S) showed non-significant effect on leaf area. Maximum leaf area (47.75 cm^2) was recorded in treatment combination T_6S_1, which was statistically at par with the treatment combination T_5S_1, T_3S_1, $T_{10}S_1$, T_9S_1, T_1S_1, T_8S_1, T_2S_1, T_4S_1, $T_{11}S_1$, $T_{13}S_1$, $T_{12}S_1$ and T_7S_1 and minimum (13.58 cm^2) was recorded $T_{10}S_2$.

Table 6. Effect of different mulch and manures on leaf area (cm^2) of strawberry under pomegranate-based agroforestry system

Planting condition / Treatment	leaf area (cm^2)		
	S_1 (Canopy)	S_2 (Open)	Mean
T_1 (Control)	44.19	16.77	**30.48^{ab}**
T_2 (Bamboo mulch alone)	41.44	16.43	**28.93^{ab}**
T_3 (Bamboo mulch + Natural farming)	45.81	15.44	**30.62^{ab}**
T_4 (Bamboo mulch+ RDF)	41.24	15.09	**28.17^{ab}**
T_5 (Bamboo mulch+ FYM)	46.49	18.52	**32.50^{ab}**
T_6 (Pine mulch alone)	47.75	25.23	**36.49^{a}**
T_7 (Pine mulch+ Natural farming)	37.49	16.67	**27.96^{b}**
T_8 (Pine mulch+ RDF)	43.77	16.14	**29.96^{ab}**
T_9 (Pine mulch+ FYM)	45.04	18.23	**31.63^{ab}**
T_{10} (Poplar mulch alone)	45.67	13.58	**29.62^{ab}**
T_{11} (Poplar mulch + Natural farming)	40.25	14.23	**27.24^{b}**
T_{12} (Poplar mulch+ RDF)	38.15	15.09	**26.62^{b}**
T_{13} (Poplar mulch+ FYM)	38.27	18.85	**28.56^{ab}**
Mean	**42.73^{x}**	**16.94^{y}**	
$CD_{(0.05)}$			
T NS			
S 3.36			
T × S NS			

4.2.1.4 Number of leaves

The data in respect to number of leaves recorded and presented in Table 7 expressed the effect of mulches and manures on leaf area of strawberry under wild pomegranate-based agroforestry system.

The data presented in Table 7 revealed that different treatments exerted significant effect on number of leaves of strawberry under wild pomegranate-based agroforestry system. The maximum (26.27) number of leaves was recorded in treatment T_{12}, which was significantly similar with T_2. Minimum number of leaves (17.73) was found in treatment T_4.

The planting conditions had significant effect on number of leaves, as maximum number of leaves (24.40) was recorded under S_1 (agroforestry system) and the minimum number of leaves (15.23) was recorded under S_2 (open condition).

The combined effect of planting condition and treatment (T×S) showed significant effect on number of leaves. Maximum number of leaves (34.20) was recorded in treatment combination $T_{12}S_1$, which was statistically at par with the treatment combination T_2S_1 and minimum (13.96) was recorded in T_1S_2.

Table 7. Effect of mulch and manure on number of leaves in strawberry under pomegranate-based agroforestry system

Planting condition / Treatment	Number of leaves		
	S_1 (Closed)	S_2 (Open)	Mean
T_1 (Control)	21.40	13.96	**17.93^{e}**
T_2 (Bamboo mulch alone)	28.47	18.00	**23.23^{ab}**
T_3 (Bamboo mulch + Natural farming)	22.07	14.80	**18.43^{de}**
T_4 (Bamboo mulch+ RDF)	21.07	14.40	**17.73^{e}**
T_5 (Bamboo mulch+ FYM)	23.00	15.00	**19.00^{de}**
T_6 (Pine mulch alone)	20.20	15.40	**17.80^{e}**
T_7 (Pine mulch+ Natural farming)	25.40	14.40	**19.90^{cde}**
T_8 (Pine mulch+ RDF)	30.20	14.13	**22.17^{bc}**
T_9 (Pine mulch+ FYM)	19.80	15.80	**17.80^{e}**
T_{10} (Poplar mulch alone)	21.67	14.47	**18.07^{de}**
T_{11} (Poplar mulch + Natural farming)	27.53	14.87	**21.20^{bcd}**
T_{12} (Poplar mulch+ RDF)	34.20	18.33	**26.27^{a}**
T_{13} (Poplar mulch+ FYM)	22.20	14.40	**18.30^{de}**
Mean	**24.40^{x}**	**15.23^{y}**	
$CD_{(0.05)}$ **T** 3.22 **S** 1.26 **T × S** 4.56			

4.2.1.5 Total Chlorophyll Content (SPAD)

The data in respect of the effect of mulches and manures on of strawberry under wild pomegranate-based agroforestry system had been recorded and presented in Table 8.

It can be deduced from the data presented in Table 8 different treatments exerted significant effect on total chlorophyll content of strawberry under wild pomegranate-based agroforestry system. The maximum (42.47 SPAD) total chlorophyll content was recorded in treatment T_7, which was statistically at par with T_8, T_6. Minimum total chlorophyll content (32.03 SPAD) was observed in treatment T_1.

The planting conditions had significant effect on total chlorophyll content, as maximum total chlorophyll content (38.86 SPAD) was recorded under S_1 (agroforestry system) and the minimum total chlorophyll content (34.46 SPAD) was recorded under S_2 (open condition).

The combined effect of planting condition and treatment (T×S) showed non-significant effect on total chlorophyll content.

Table 8. **Effect of different mulch and manures on total chlorophyll content (SPAD) in strawberry under pomegranate-based agroforestry system**

Treatment / Planting condition	Total Chlorophyll Content (SPAD)		
	S_1 (Closed)	S_2 (Open)	Mean
T_1 (Control)	34.79	33.98	**32.03^d**
T_2 (Bamboo mulch alone)	39.97	35.16	**32.04^d**
T_3 (Bamboo mulch + Natural farming)	39.52	36.19	**39.92^b**
T_4 (Bamboo mulch+ RDF)	34.45	36.62	**34.34^{cd}**
T_5 (Bamboo mulch+ FYM)	38.01	36.20	**36.34^c**
T_6 (Pine mulch alone)	43.16	35.77	**40.30^{ab}**
T_7 (Pine mulch+ Natural farming)	44.66	37.84	**42.47^a**
T_8 (Pine mulch+ RDF)	45.86	36.63	**40.55^{ab}**
T_9 (Pine mulch+ FYM)	41.89	36.30	**34.93^c**
T_{10} (Poplar mulch alone)	40.54	36.51	**35.92^c**
T_{11} (Poplar mulch + Natural farming)	39.69	36.16	**36.45^c**
T_{12} (Poplar mulch+ RDF)	36.78	36.82	**34.96^c**
T_{13} (Poplar mulch+ FYM)	37.19	33.93	**36.42^c**
Mean	**38.86^x**	**34.46^y**	
$CD_{(0.05)}$ **T** 2.49 **S** 0.98 **T × S** NS			

Mulch increased height of plants as the soil under the mulch remained loose and thoroughly aerated may have attributed in increased root activity in soil. The maximum value of plant height was best recorded in poplar mulch with Farm yard manure (Table 4-5) which possibly attributed to the better aeration around plant rhizosphere creating favorable environment for nutrient uptake and translocate it to the whole plants for synthesis of food material which than is regularly supplied to the different parts of the plant. All organic mulches conserved the soil moisture which helped in continuous supply of water and decomposition of different organic mulches added nutrient in the soil and then these nutrients were supplied to the plant throughout the growing stage. Organic and inorganic nutrient sources had a major impact on the growth of plant. The slow decomposition of FYM helped in increasing the plant spread of the plant. As, inorganic nutrient sources are readily available to the plant which directly influence the plant height, number of leaves and leaf area (Table 6-7) which was significantly affected by the mulches. Agroforestry helps in environment amelioration and the canopy of wild pomegranate significantly affect the various growth parameters of strawberry (Table 7). The canopy of the tree regulated the day and night temperature. Agroforestry trees enhances the amount of nutrients uptake from deeper horizons, weathering of soil minerals and pumping the nutrients into the canopy. Agroforestry also enhances soil fertility by supporting soil biological activities. Results revealed that application of jeevamrut to plants produced better foliage with dark green colored leaves (Table 8) which means when chlorophyll content is more photosynthates were produced.

The results are in accordance with work of Misra (1996); Sujatha *et al.* (2018); Angrej and Gaur (2013); Das *et al.* (2010); Moor *et al.* (2004); Aweto and Iyanda (2003); Adnan *et al.* (2017); Verma et al. (2021); Ghandhar *et al.* (2020); Islam *et al.* (2002); Singh *et al.* (2015); Kayum *et al.* (2008); Fayaz *et al.* (2016); El-Shal *et al.* (2003); Suge *et al.* (2011).

4.2.2 Yield parameter of *Fragaria× ananassa* Duch.

4.2.2.1 Number of flowers

Critical examination of the Table 9 revealed that different treatments exerted significant effect on number of flowers of strawberry under wild pomegranate-based agroforestry system. The maximum (33.39) number of flowers was recorded in treatment T_8, which is statistically at par with T_7, T_9. Minimum number of flowers (19.81) was recorded in treatment T_1 (control).

Table 9. Effect of different mulch and manures on number of flowers of strawberry under pomegranate-based agroforestry system

Treatment / Planting condition	Number of flowers		
	S_1 (Canopy)	S_2 (Open)	Mean
T_1 (Control)	24.40	15.22	**19.81^{f}**
T_2 (Bamboo mulch alone)	30.73	26.00	**28.37^{de}**
T_3 (Bamboo mulch + Natural farming)	33.20	26.67	**29.93^{cd}**
T_4 (Bamboo mulch+ RDF)	35.20	27.22	**31.21^{bc}**
T_5 (Bamboo mulch+ FYM)	35.47	27.55	**28.92^{bc}**
T_6 (Pine mulch alone)	34.93	27.33	**31.13^{bc}**
T_7 (Pine mulch+ Natural farming)	35.93	27.67	**31.80^{ab}**
T_8 (Pine mulch+ RDF)	38.33	28.44	**33.39^{a}**
T_9 (Pine mulch+ FYM)	35.70	28.89	**32.29^{ab}**
T_{10} (Poplar mulch alone)	30.53	25.00	**27.77^{e}**
T_{11} (Poplar mulch + Natural farming)	31.40	28.56	**29.98^{cd}**
T_{12} (Poplar mulch+ RDF)	34.33	27.00	**30.67^{bc}**
T_{13} (Poplar mulch+ FYM)	35.53	27.44	**31.49^{bc}**
Mean	**33.51^{x}**	**26.38^{y}**	
$CD_{(0.05)}$ **T** 1.74 **S** 0.68 **T × S** 2.46			

The planting conditions had significant effect on number of flowers, as maximum number of flowers (33.51) was recorded under S_1 (agroforestry system) and the minimum number of flowers (26.38) was recorded under S_2 (open condition).

The combined effect of planting condition and treatment (T×S) showed significant effect on number of flowers. Maximum number (38.33) flowers were recorded in treatment combination T_8S_1, which was statistically at par with the treatment combination T_7S_1 and minimum (15.22) was recorded in T_1S_2.

4.2.2.2 Fruit set (%)

The observations regarding the effect of mulches and manures on percent fruit set of strawberry under wild pomegranate-based agroforestry system had been recorded and presented in Table 10.

Table 10. Effect of different mulch and manures on fruit set (%) of strawberry under pomegranate-based agroforestry system

Planting condition / Treatment	Fruit set (%)		
	S_1 (Canopy)	S_2 (Open)	Mean
T_1 (Control)	64.70	64.08	**64.39^{cd}**
T_2 (Bamboo mulch alone)	68.87	69.70	**69.28^{abc}**
T_3 (Bamboo mulch + Natural farming)	64.41	70.93	**67.67^{abc}**
T_4 (Bamboo mulch+ RDF)	60.41	72.56	**66.49^{abcd}**
T_5 (Bamboo mulch+ FYM)	64.75	66.18	**65.47^{bcd}**
T_6 (Pine mulch alone)	60.53	74.77	**67.65^{abc}**
T_7 (Pine mulch+ Natural farming)	65.06	76.72	**70.89^{ab}**
T_8 (Pine mulch+ RDF)	68.66	75.80	**72.23^{a}**
T_9 (Pine mulch+ FYM)	66.48	70.39	**68.43^{abc}**
T_{10} (Poplar mulch alone)	64.04	66.36	**65.20^{bcd}**
T_{11} (Poplar mulch + Natural farming)	68.83	63.83	**66.41^{abcd}**
T_{12} (Poplar mulch+ RDF)	61.94	66.81	**64.37^{cd}**
T_{13} (Poplar mulch+ FYM)	58.37	63.15	**60.76^{d}**
Mean	**64.40^{y}**	**69.33^{x}**	
$CD_{(0.05)}$ **T** NS **S** 2.45 **T × S** NS			

Analysis of the data presented in Table 10 showed different treatments exerted non-significant effect on fruit set of strawberry under wild pomegranate-based agroforestry system.

The planting conditions had significant effect on fruit set, as maximum fruit set (69.33 %) was recorded in S_2 (open condition) and the minimum fruit set (64.40 %) was recorded in S_1 (agroforestry system).

The combined effect of planting condition and treatment (T×S) showed non-significant effect on fruit set.

4.2.2.3 Number of fruits

A glance at Table 11 represented different treatments exerted significant effect on number of fruits of strawberry under wild pomegranate-based agroforestry system.

The maximum (23.91) was recorded in treatment T_8. Minimum number of fruits (12.49) was observed in treatment T_1.

Table 11. Effect of different mulch and manures on number of fruits per plant of strawberry under pomegranate-based agroforestry system

Treatment / Planting condition	Number of fruits		
	S_1 (Closed)	S_2 (Open)	Mean
T_1 (Control)	15.20	9.80	**12.49^{f}**
T_2 (Bamboo mulch alone)	22.93	18.22	**20.58^{cd}**
T_3 (Bamboo mulch + Natural farming)	21.33	18.89	**20.11^{cd}**
T_4 (Bamboo mulch+ RDF)	21.27	19.78	**20.52^{c}**
T_5 (Bamboo mulch+ FYM)	21.00	18.11	**19.56^{c}**
T_6 (Pine mulch alone)	21.13	20.44	**20.79^{c}**
T_7 (Pine mulch+ Natural farming)	23.33	21.22	**22.28^{b}**
T_8 (Pine mulch+ RDF)	26.27	21.55	**23.91^{a}**
T_9 (Pine mulch+ FYM)	23.73	20.33	**22.03^{b}**
T_{10} (Poplar mulch alone)	19.47	16.56	**18.01^{e}**
T_{11} (Poplar mulch + Natural farming)	21.60	18.22	**19.91^{cd}**
T_{12} (Poplar mulch+ RDF)	21.27	18.00	**19.63^{cd}**
T_{13} (Poplar mulch+ FYM)	20.73	17.33	**19.03^{de}**
Mean	**21.48^{x}**	**18.34^{y}**	

$CD_{(0.05)}$
T 1.24
S 0.49
T × S 1.76

The planting conditions had significant effect on number of fruits, as maximum number of fruits (21.48) was recorded in S_1 (agroforestry system) and the minimum number of fruits (18.34) was recorded in S_2 (open condition).

The combined effect of planting condition and treatment (T×S) showed significant effect on number of fruits. Maximum number of fruits (26.27) was found in treatment combination T_8S_1 and minimum (9.80) was found in T_1S_2.

4.2.2.4 Yield per plant (g)

The data pertaining to the effect of different mulch and manures on yield per plant of strawberry under wild pomegranate-based agroforestry system had been recorded and presented in Table 12.

Table 12. Effect of different mulch and manures on yield per plant (g) of strawberry under pomegranate-based agroforestry system

Treatment / Planting condition	Yield per plant (g)		
	S_1 (Closed)	S_2 (Open)	Mean
T_1 (Control)	225.78	114.01	**169.89^{f}**
T_2 (Bamboo mulch alone)	333.60	233.99	**283.79^{cde}**
T_3 (Bamboo mulch + Natural farming)	355.38	247.62	**301.50^{bcd}**
T_4 (Bamboo mulch+ RDF)	347.24	275.55	**311.39^{bc}**
T_5 (Bamboo mulch+ FYM)	338.50	259.53	**299.02^{bcde}**
T_6 (Pine mulch alone)	324.39	278.03	**301.21^{bcd}**
T_7 (Pine mulch+ Natural farming)	359.51	288.74	**324.12^{b}**
T_8 (Pine mulch+ RDF)	422.01	296.90	**359.46^{a}**
T_9 (Pine mulch+ FYM)	423.69	299.28	**361.48^{a}**
T_{10} (Poplar mulch alone)	300.74	237.63	**269.19^{e}**
T_{11} (Poplar mulch + Natural farming)	371.77	240.61	**306.19^{bc}**
T_{12} (Poplar mulch+ RDF)	351.44	231.54	**266.59^{cde}**
T_{13} (Poplar mulch+ FYM)	327.29	219.95	**273.62^{de}**
Mean	**344.72^{x}**	**247.96^{y}**	
$CD_{(0.05)}$ **T** 31.24 **S** 12.25 **T × S** NS			

A cursory look at the data presented in Table 12 revealed that different treatments exerted significant effect on yield per plant of strawberry under wild pomegranate-based agroforestry system. The maximum (361.48 g) yield per plant was recorded in treatment T_9, which is significantly at par with T_8. Minimum yield per plant (169.89 g) was observed in treatment T_1.

The planting conditions had significant effect on yield per plant, as maximum yield per plant (344.72 g) was recorded in S_1 (agroforestry system) and the minimum yield per plant (247.96 g) was recorded in S_2 (open condition).

The combined effect of planting condition and treatment (T×S) showed non-significant effect on yield per plant.

4.2.2.5 Yield per hectare (ton ha^{-1})

The data pertaining to the effect of different mulch and manures on yield per hectare of strawberry under wild pomegranate-based agroforestry system had been recorded and presented in table 13.

Table 13. Effect of different mulch and manures on yield per hectare (ton ha^{-1}) of strawberry under pomegranate-based agroforestry system

Treatment / Planting condition	Yield per hectare (ton ha^{-1})		
	S_1 (Closed)	S_2 (Open)	Mean
T_1 (Control)	6.01	2.577	**4.29^{f}**
T_2 (Bamboo mulch alone)	8.87	5.27	**7.07^{cde}**
T_3 (Bamboo mulch + Natural far ming)	9.45	5.57	**7.51^{bcd}**
T_4 (Bamboo mulch+ RDF)	9.23	6.20	**7.72^{bc}**
T_5 (Bamboo mulch+ FYM)	9.00	5.84	**7.42^{bcde}**
T_6 (Pine mulch alone)	8.63	6.26	**7.44^{bcd}**
T_7 (Pine mulch+ Natural farming)	9.56	6.50	**8.03^{b}**
T_8 (Pine mulch+ RDF)	11.23	6.68	**8.95^{a}**
T_9 (Pine mulch+ FYM)	11.27	6.74	**9.00^{a}**
T_{10} (Poplar mulch alone)	8.00	5.34	**6.67^{e}**
T_{11} (Poplar mulch + Natural farming)	9.35	5.21	**7.28^{bc}**
T_{12} (Poplar mulch+ RDF)	9.35	5.21	**7.28^{bcde}**
T_{13} (Poplar mulch+ FYM)	8.71	4.95	**6.83^{de}**
Mean	**9.17^{x}**	**5.58^{y}**	
CD$_{(0.05)}$			
T 0.76			
S 0.30			
T × S NS			

The data garnered in Table 13 revealed that different treatments exerted significant effect on yield per hectare of strawberry under wild pomegranate-based agroforestry system. The maximum (9.00 ton/ha) yield per hectare was recorded in treatment T_9, which is significantly at par with T_8. Minimum yield per hectare (4.29 ton/ha) was recorded in treatment T_1 (control).

The planting conditions had significant effect on yield per hectare, as maximum yield per hectare (9.17 ton/ha) was recorded in S_1 (agroforestry system) and the minimum yield per hectare (5.58 ton/ha) was recorded in S_2 (open condition).

The combined effect of planting condition and treatment (T×S) showed non-significant effect on number of flowers.

The application of organic mulch along with RDF significantly increased the soil nutrient status and mulches also enhanced the soil moisture content which further supported the uptake of nutrients from soil and consequently promoted better plant growth in mulched plots as compared to control. This might be a plausible reason for the increase in number of flowers per plant. The average fruit set and number of fruits are positively correlated to the number of flowers. As maximum number of flowers were obtained under T_8 (Pine mulch + RDF), consequently number of fruits and average fruit set increased under this treatment.

Due to favorable moisture and temperature conditions the yield of mulched plots reported maximum yield. According to correlation analysis, a positive correlation was observed between yield, growth and soil parameter. Application of mulch significantly enhanced the above stated parameters, due to which overall yield increased. Another reason may be the reduction in weed infestation due to mulching. Addition of FYM further enhanced the soil nutrient status. Consequently, highest yield was obtained in the treatment where FYM was added along with organic mulch. Tree under agroforestry lower the excessive heat and moderates the influence on flower conduction and fruiting. According to the study, fruits grown under tree in agroforestry were superior in quality and yielded better than sole cropping. The results revealed that maximum number of flowers were obtained with the application of NPK in two split doses, as NPK provided better nutrition to the plants and help in accelerating the meristematic activity of the plants.

The results are supported by the findings of Kaur and Brar (2016); Alhrout *et al.* (2018); Umar *et al.* (2009); Ali *et al.* (2023); El-Shal *et al.* (2003); Singh *et al.* (2015),

4.2.3 Fruit quality parameter of *Fragaria*× *ananassa* Duch.

4.2.3.1 Fruit length (mm)

Critical examination of the data presented in Table 14 revealed that different treatments exerted significant effect on number of flowers of strawberry under wild pomegranate-based agroforestry system.

Table 14. Effect of different mulch and manures on fruit length (mm) of strawberry under pomegranate-based agroforestry system

Treatment / Planting condition	Fruit length(mm)		
	S_1 (Closed)	S_2 (Open)	Mean
T_1 (Control)	33.87	29.16	**31.51^{e}**
T_2 (Bamboo mulch alone)	37.21	30.67	**33.94^{bcde}**
T_3 (Bamboo mulch + Natural farming)	35.75	31.99	**33.87^{bcde}**
T_4 (Bamboo mulch+ RDF)	37.91	32.50	**35.20^{abcd}**
T_5 (Bamboo mulch+ FYM)	37.97	31.79	**34.88^{bcd}**
T_6 (Pine mulch alone)	37.28	31.38	**34.33^{bcde}**
T_7 (Pine mulch+ Natural farming)	38.21	34.09	**36.15^{abc}**
T_8 (Pine mulch+ RDF)	41.09	32.34	**36.71^{ab}**
T_9 (Pine mulch+ FYM)	41.71	34.43	**38.07^{a}**
T_{10} (Poplar mulch alone)	35.22	29.98	**32.60^{de}**
T_{11} (Poplar mulch + Natural farming)	35.89	31.21	**33.55^{cde}**
T_{12} (Poplar mulch+ RDF)	38.85	31.12	**34.98^{bcd}**
T_{13} (Poplar mulch+ FYM)	38.35	30.63	**34.49^{bcde}**
Mean	**37.64^{x}**	**31.64^{y}**	

$CD_{(0.05)}$
T 3.08
S 1.21
T × S NS

The inquisition of the data that different treatments exerted significant effect on fruit length of strawberry under wild pomegranate-based agroforestry system. The maximum (38.07 mm) fruit length was recorded in treatment T_9, which was statistically at similar with T_8, T_7, T_4. Minimum fruit length (31.51 mm) was recorded in treatment T_1.

The planting conditions had significant effect on fruit length, as maximum fruit length (37.64 mm) was recorded under S_1 (agroforestry system) and the minimum fruit length (31.64 mm) was recorded under S_2 (open condition).

Plate 3. Laboratory evaluation of Strawberry

The combined effect of planting condition and treatment (T×S) showed non-significant effect on fruit length.

4.2.3.2 Fruit diameter (mm)

The data presented in Table 15 predicts the effect of different mulches and manures on of strawberry under wild pomegranate-based agroforestry system had been recorded and presented in Table 15.

Table 15. Effect of different mulch and manures on fruit diameter (mm) of strawberry under pomegranate-based agroforestry system

Planting condition / Treatment	Fruit diameter (mm)		
	S_1 (Closed)	S_2 (Open)	Mean
T_1 (Control)	24.98	21.64	**23.31^{e}**
T_2 (Bamboo mulch alone)	27.38	21.97	**24.67^{de}**
T_3 (Bamboo mulch + Jeevamrut)	29.11	23.87	**26.49^{abcd}**
T_4 (Bamboo mulch+ RDF)	29.72	24.46	**27.09^{abc}**
T_5 (Bamboo mulch+ FYM)	29.37	23.58	**26.48^{abcd}**
T_6 (Pine mulch alone)	28.56	23.60	**26.08^{bcde}**
T_7 (Pine mulch+ Jeevamrut)	30.82	27.84	**29.33^{a}**
T_8 (Pine mulch+ RDF)	32.19	25.39	**28.79^{ab}**
T_9 (Pine mulch+ FYM)	29.87	22.61	**26.24^{bcd}**
T_{10} (Poplar mulch alone)	28.20	22.80	**25.50^{cde}**
T_{11} (Poplar mulch +Jeevamrut)	28.78	25.49	**27.13^{abcd}**
T_{12} (Poplar mulch+ RDF)	30.29	23.44	**26.86^{abcd}**
T_{13} (Poplar mulch+ FYM)	28.60	22.17	**25.38^{cde}**
Mean	**29.06^{x}**	**23.86^{y}**	

$CD_{(0.05)}$
T 2.86
S 1.12
T × S NS

The perusal of data presented in Table 12 revealed that different treatments exerted significant effect on fruit diameter of strawberry under wild pomegranate-based agroforestry system. The maximum (29.33 mm) fruit diameter was recorded in treatment T_7, which was statistically at par with T_8, T_{11}, T_4, T_3, T_5, and T_{12}. Minimum fruit diameter (23.31 mm) was recorded in treatment T_1 (control).

The planting conditions had significant effect on fruit diameter, as maximum fruit diameter (29.06 mm) was recorded under S_1 (agroforestry system) and the minimum fruit diameter (23.86 mm) was recorded under S_2 (open condition).

The combined effect of planting condition and treatment (T×S) showed non-significant effect on fruit diameter.

4.2.3.3 Fruit weight (g)

It can be deduced from the data represented in Table 16 that different treatments exerted significant effect on fruit weight of strawberry under wild pomegranate-based agroforestry system. The maximum (15.66 g) was recorded in treatment T_9, which was statistically at similar with T_{11}, T_4, T_3, T_5, T_6, T_7, T_8, T_{10}, T_{11} and T_{12}. Minimum fruit weight (13.22 g) was observed in treatment T_1(Control).

The planting conditions had significant effect on fruit weight, as maximum fruit weight (16.06 g) was recorded under S_1 (agroforestry system) and the minimum fruit weight (13.37 g) was recorded under S_2 (open condition).

Table 16. Effect of different mulch and manures on fruit weight (g) of strawberry under pomegranate-based agroforestry system

Planting condition / Treatment	Fruit weight (g)		
	S_1 (Closed)	S_2 (Open)	Mean
T_1 (Control)	14.86	11.60	**13.22^{d}**
T_2 (Bamboo mulch alone)	15.87	12.90	**14.38^{bcd}**
T_3 (Bamboo mulch + Jeevamrut)	16.65	13.12	**14.88^{abc}**
T_4 (Bamboo mulch+ RDF)	16.32	13.86	**15.09^{abc}**
T_5 (Bamboo mulch+ FYM)	14.80	14.25	**14.52^{abc}**
T_6 (Pine mulch alone)	15.36	13.53	**14.44^{abc}**
T_7 (Pine mulch+ Jeevamrut)	15.41	13.58	**14.50^{abc}**
T_8 (Pine mulch+ RDF)	16.07	14.12	**14.93^{abc}**
T_9 (Pine mulch+ FYM)	17.85	14.07	**15.66^{a}**
T_{10} (Poplar mulch alone)	15.44	14.03	**14.73^{abc}**
T_{11} (Poplar mulch +Jeevamrut)	17.84	13.24	**15.54^{ab}**
T_{12} (Poplar mulch+ RDF)	16.51	12.86	**14.68^{abc}**
T_{13} (Poplar mulch+ FYM)	15.78	12.71	**14.24^{cd}**
Mean	**16.06^{x}**	**13.37^{y}**	
$CD_{(0.05)}$ **T** 1.22 **S** 0.48 **T× S** NS			

The combined effect of planting condition and treatment (T×S) showed non-significant effect on fruit weight.

Organic mulches and manures are beneficial as they bridge gap between nutrient removal & delivery and also ensure balanced nutrient proportion which results in enhanced growth and productivity of plants. The maximum fruit length, weight and diameter might be attributed to the less competition for space and nutrients due to reduction in weed infestation which ultimately provided more space and nutrient absorption by plants resulting in better fruit morphological characters viz.; length, weight and diameter. The increase in vegetative parameters might be due to the full coverage to the soil provided by organic mulch materials as mulch hampers plants with great moisture retention.

The results of the present investigation are substantiated with the previous findings of Soni *et al*. (2018): Adil *et al*. (2015).

4.2.4 Physico-chemical quality parameter of *Fragaria× ananassa* Duch.

4.2.4.1 Total soluble solids (ºB)

The data regarding the effect of mulches and manures on of strawberry under wild pomegranate-based agroforestry system had been recorded and presented in Table 17.

It is evident from the data that different treatments exerted significant effect on total soluble solids of strawberry under wild pomegranate-based agroforestry system. The maximum (8.47 ºB) total soluble solids were recorded in treatment T_4, which is statistically at par with T_3, T_8. Minimum total soluble solids (7.23 ºB) were recorded in treatment T_1.

The planting conditions had significant effect on total soluble solids, as maximum total soluble solids (7.96 ºB) were recorded under S_1 (agroforestry system) and the minimum total soluble solids (7.71 ºB) was recorded under S_2 (open condition).

The combined effect of planting condition and treatment (T×S) showed non-significant effect on total soluble solids.

Table 17. Effect of different mulch and manures on Total soluble solids (°B) in strawberry under pomegranate-based agroforestry system

Treatment / Planting condition	Total soluble solids (°B)		
	S_1 (Closed)	S_2 (Open)	Mean
T_1 (Control)	7.31	7.14	**7.23^{e}**
T_2 (Bamboo mulch alone)	7.56	7.35	**7.45^{de}**
T_3 (Bamboo mulch + Natural farming)	8.34	8.08	**8.21^{ab}**
T_4 (Bamboo mulch+ RDF)	8.63	8.31	**8.47^{a}**
T_5 (Bamboo mulch+ FYM)	7.91	7.55	**7.73^{cd}**
T_6 (Pine mulch alone)	7.90	7.65	**7.78^{cd}**
T_7 (Pine mulch+ Natural farming)	7.97	7.49	**7.72^{cd}**
T_8 (Pine mulch+ RDF)	8.41	8.22	**8.32^{ab}**
T_9 (Pine mulch+ FYM)	8.14	7.95	**8.04^{bc}**
T_{10} (Poplar mulch alone)	7.68	7.46	**7.57^{de}**
T_{11} (Poplar mulch + Natural farming)	7.34	7.22	**7.28^{e}**
T_{12} (Poplar mulch+ RDF)	8.11	7.97	**8.04^{bc}**
T_{13} (Poplar mulch+ FYM)	8.17	7.81	**7.99^{bc}**
Mean	**7.96^{x}**	**7.71^{y}**	
$CD_{(0.05)}$ **T** 0.35 **S** 0.14 **T × S** NS			

4.2.4.2 Titratable acidity (%)

The perusal of data presented in table 18 revealed that different treatments exerted significant effect on titratable acidity of strawberry under wild pomegranate-based agroforestry system. The maximum (0.45 %) titratable acidity was recorded in treatment T_9, which was statistically at par with T_4. Minimum titratable acidity (0.25 %) was recorded in treatment T_1 (control).

The planting conditions had significant effect on titratable acidity, as maximum titratable acidity (0.38 %) was recorded under S_1 (agroforestry system) and the minimum titratable acidity (0.35 %) was recorded under S_2 (open condition).

The combined effect of planting condition and treatment (T×S) showed non-significant effect on titratable acidity.

Table 18. Effect of different mulch and manures on Titratable acidity (%) in strawberry under pomegranate-based agroforestry system

Treatment / Planting condition	Titratable acidity (%)		
	S_1 (Closed)	S_2 (Open)	Mean
T_1 (Control)	0.26	0.23	**0.25[h]**
T_2 (Bamboo mulch alone)	0.42	0.39	**0.40[c]**
T_3 (Bamboo mulch + Natural farming)	0.38	0.35	**0.36[d]**
T_4 (Bamboo mulch+ RDF)	0.44	0.43	**0.43[ab]**
T_5 (Bamboo mulch+ FYM)	0.40	0.37	**0.39[c]**
T_6 (Pine mulch alone)	0.35	0.33	**0.34[e]**
T_7 (Pine mulch+ Natural farming)	0.41	0.38	**0.39[c]**
T_8 (Pine mulch+ RDF)	0.44	0.40	**0.42[b]**
T_9 (Pine mulch+ FYM)	0.47	0.42	**0.45[a]**
T_{10} (Poplar mulch alone)	0.42	0.36	**0.39[c]**
T_{11} (Poplar mulch + Natural farming)	0.32	0.30	**0.31[f]**
T_{12} (Poplar mulch+ RDF)	0.35	0.32	**0.33[e]**
T_{13} (Poplar mulch+ FYM)	0.29	0.25	**0.27[g]**
Mean	**0.38[x]**	**0.35[y]**	
$CD_{(0.05)}$ **T** 0.02 S 0.01 **T × S** NS			

4.2.4.3 TSS: acid ratio

The data pertaining to the effect of different mulch and manures on yield per hectare of strawberry under wild pomegranate-based agroforestry system had been recorded and presented in Table 19.

It can be deduced from the data represented in Table 19 that different treatments exerted significant effect on TSS/ acid ratio of strawberry under wild pomegranate-based agroforestry system. The maximum (29.42) was recorded in treatment T_1, which is significantly at with T_{13}. Minimum TSS/ acid ratio (18.02) was observed in treatment T_9.

The planting conditions had significant effect on TSS/ acid ratio, as maximum TSS/ acid ratio (22.62) was recorded under S_2 (open condition) and the minimum TSS/ acid ratio (21.46) was recorded under S_1 (agroforestry system).

The combined effect of planting condition and treatment (T×S) showed non-significant effect on number of fruits.

Table 19. Effect of different mulch and manures on TSS/ acid ratio in strawberry under pomegranate-based agroforestry system

Treatment \ Planting condition	TSS/ acid ratio		
	S_1 (Closed)	S_2 (Open)	Mean
T_1 (Control)	28.23	30.61	**29.42^{a}**
T_2 (Bamboo mulch alone)	18.10	19.08	**18.59^{cd}**
T_3 (Bamboo mulch + Natural farming)	21.75	23.41	**22.58^{b}**
T_4 (Bamboo mulch+ RDF)	19.55	19.35	**19.45^{cd}**
T_5 (Bamboo mulch+ FYM)	19.69	20.41	**20.06^{c}**
T_6 (Pine mulch alone)	22.65	23.13	**22.89^{b}**
T_7 (Pine mulch+ Natural farming)	19.44	19.51	**19.47^{cd}**
T_8 (Pine mulch+ RDF)	18.98	20.38	**19.68^{cd}**
T_9 (Pine mulch+ FYM)	17.30	18.73	**18.02^{d}**
T_{10} (Poplar mulch alone)	18.42	20.54	**19.48^{cd}**
T_{11} (Poplar mulch + Natural farming)	23.08	23.92	**23.50^{b}**
T_{12} (Poplar mulch+ RDF)	23.37	24.75	**24.06^{b}**
T_{13} (Poplar mulch+ FYM)	28.44	30.29	**29.37^{a}**
Mean	**21.46^{y}**	**22.62^{x}**	
CD$_{(0.05)}$ **T** 1.79 **S** 0.70 **T × S** NS			

4.2.4.4 Total sugar (%)

The observations regarding the effect of mulches and manures on of strawberry under wild pomegranate-based agroforestry system had been recorded and presented in Table 20.

It is evident from the data that different treatments exerted significant effect on total sugars of strawberry under wild pomegranate-based agroforestry system. The maximum (6.20 %) total sugar were recorded in treatment T_8, which was statistically at similar with T_9, T_5, T_4, T_{11}, T_7, T_{13}, T_6. Minimum total sugars (5.37 %) were recorded in treatment T_1 (control).

The planting conditions had significant effect on total sugars, as maximum total sugars (6.84 %) were recorded under S_1 (agroforestry system) and the minimum total sugars (4.92 %) was recorded under S_2 (open condition).

The combined effect of planting condition and treatment (T×S) showed non-significant effect on total sugars.

Table 20. Effect of different mulch and manures on Total sugars (%) in strawberry under pomegranate-based agroforestry system

Planting condition / Treatment	Total sugars (%)		
	S_1 (Closed)	S_2 (Open)	Mean
T_1 (Control)	6.18	4.56	**5.37**^{d}
T_2 (Bamboo mulch alone)	6.40	4.99	**5.70**^{cd}
T_3 (Bamboo mulch + Natural farming)	6.60	5.05	**5.83**^{bc}
T_4 (Bamboo mulch+ RDF)	7.09	4.95	**6.02**^{abc}
T_5 (Bamboo mulch+ FYM)	7.06	5.07	**6.07**^{ab}
T_6 (Pine mulch alone)	7.01	4.69	**5.85**^{abc}
T_7 (Pine mulch+ Natural farming)	7.05	4.92	**5.98**^{abc}
T_8 (Pine mulch+ RDF)	7.27	5.13	**6.20**^{a}
T_9 (Pine mulch+ FYM)	7.16	5.02	**6.09**^{ab}
T_{10} (Poplar mulch alone)	6.59	4.74	**5.67**^{cd}
T_{11} (Poplar mulch + Natural farming)	7.10	4.92	**6.01**^{abc}
T_{12} (Poplar mulch+ RDF)	6.65	4.87	**5.76**^{bc}
T_{13} (Poplar mulch+ FYM)	6.72	4.99	**5.85**^{abc}
Mean	**6.84**^{x}	**4.92**^{y}	
CD$_{(0.05)}$ **T** 0.37 **S** 0.14 **T × S** NS			

4.2.4.5 Reducing sugar (%)

The data regarding the effect of different mulches and manures on of strawberry under wild pomegranate-based agroforestry system had been recorded and presented in Table 21.

It can be deduced from the data represented in Table 21 that different treatments exerted significant effect on reducing sugars of strawberry under wild pomegranate-based agroforestry system. The maximum (4.82 %) was recorded in treatment T_8 which was statistically at similar with T_5, T_{11}, T_7, T_6, T_9. Minimum reducing sugars (3.98 %) was observed in treatment T_1.

The planting conditions had non-significant effect on reducing sugars, as maximum reducing sugars (5.28 %) was recorded under S_1 (agroforestry system) and the minimum reducing sugars (3.52 %) was recorded under S_2 (open condition).

The combined effect of planting condition and treatment (T×S) showed significant effect on reducing sugars. Maximum reducing sugars 5.80 % was found in treatment combination T_7S_1, which is significantly at par with $T_{11}S_1$, T_8S_1, T_9S_1, T_4S_1, T_5S_1 and T_6S_1 and minimum 3.32 % was found in T_1S_2.

Table 21. Effect of different mulch and manures on reducing sugars (%) in strawberry under pomegranate-based agroforestry system

Planting condition / Treatment	Reducing sugars (%)		
	S_1 (Closed)	S_2 (Open)	Mean
T_1 (Control)	4.63	3.32	**3.98^{e}**
T_2 (Bamboo mulch alone)	4.84	3.56	**4.20^{de}**
T_3 (Bamboo mulch + Natural farming)	4.95	3.42	**4.18^{de}**
T_4 (Bamboo mulch+ RDF)	5.54	3.32	**4.43^{bcd}**
T_5 (Bamboo mulch+ FYM)	5.44	3.91	**4.67^{ab}**
T_6 (Pine mulch alone)	5.42	3.58	**4.50^{abcd}**
T_7 (Pine mulch+ Natural farming)	5.80	3.32	**4.56^{abc}**
T_8 (Pine mulch+ RDF)	5.57	4.07	**4.82^{a}**
T_9 (Pine mulch+ FYM)	5.56	3.43	**4.49^{abcd}**
T_{10} (Poplar mulch alone)	5.17	3.49	**4.34^{bcde}**
T_{11} (Poplar mulch + Natural farming)	5.64	3.58	**4.61^{abc}**
T_{12} (Poplar mulch+ RDF)	5.15	3.41	**4.29^{cde}**
T_{13} (Poplar mulch+ FYM)	4.98	3.40	**4.19^{de}**
Mean	**5.28^{x}**	**3.52^{y}**	
$CD_{(0.05)}$ **T** 0.36 **S** 0.14 **T × S** 0.51			

4.2.4.6 Non-reducing sugar (%)

The data regarding the effect of different mulches and manures on of strawberry under wild pomegranate-based agroforestry system had been recorded and presented in Table 22.

It can be deduced from the data represented in Table 22 that the different treatments exerted significant effect on non-reducing of strawberry under wild pomegranate-based agroforestry system. The maximum (1.87 %) non-reducing was recorded in treatment T_{13}, which was statistically at par with T_3, T_9, T_4, T_2, T_{12}, T_7, T_{11}, T_5, T_8, T_1. Minimum non-reducing (1.55 %) was observed in treatment T_{10}. The planting conditions had non-significant effect on non-reducing sugars.

The combined effect of planting condition and treatment (T×S) showed non-significant effect on non-reducing.

Table 22. Effect of different mulch and manures on non-reducing (%) in strawberry under pomegranate-based agroforestry system

Treatment / Planting condition	Non-reducing (%)		
	S_1 (Closed)	S_2 (Open)	Mean
T_1 (Control)	1.78	1.41	**1.59**^{abc}
T_2 (Bamboo mulch alone)	1.80	1.61	**1.71**^{abc}
T_3 (Bamboo mulch + Natural farming)	1.90	1.80	**1.85**^{ab}
T_4 (Bamboo mulch+ RDF)	1.82	1.79	**1.81**^{abc}
T_5 (Bamboo mulch+ FYM)	1.89	1.36	**1.63**^{abc}
T_6 (Pine mulch alone)	1.86	1.29	**1.57**^{bc}
T_7 (Pine mulch+ Natural farming)	1.54	1.76	**1.65**^{abc}
T_8 (Pine mulch+ RDF)	1.97	1.26	**1.62**^{abc}
T_9 (Pine mulch+ FYM)	1.88	1.77	**1.82**^{abc}
T_{10} (Poplar mulch alone)	1.68	1.42	**1.55**^{c}
T_{11} (Poplar mulch + Natural farming)	1.74	1.52	**1.63**^{abc}
T_{12} (Poplar mulch+ RDF)	1.75	1.62	**1.69**^{abc}
T_{13} (Poplar mulch+ FYM)	1.98	1.76	**1.87**^{a}
Mean	1.82^{x}	1.57^{y}	
$CD_{(0.05)}$ **T** NS S 0.11 **T × S** NS			

4.2.4.7 Anthocyanin content (%)

The data regarding the effect of different mulches and manures on of strawberry under wild pomegranate-based agroforestry system had been recorded and presented in Table 23.

The perusal of data presented in table 23 revealed that different treatments exerted significant effect on anthocyanin of strawberry under wild pomegranate-based agroforestry system. The maximum (2.45 %) anthocyanin was recorded in treatment T_3, which was statistically at similar with T_7, T_{10}, T_{13} Minimum anthocyanin (0.57 %) was recorded in treatment T_9.

The planting conditions had significant effect on anthocyanin, as maximum anthocyanin (1.83 %) was recorded under S_1 (agroforestry system) and the minimum (1.33 %) was recorded under S_2 (open condition).

The combined effect of planting condition and treatment (T×S) showed significant effect on number of flowers. Maximum anthocyanin (3.06 %) was recorded in treatment combination T_3S_1 and minimum (0.42 %) was recorded in T_1S_2.

Table 23. Effect of different mulch and manures on anthocyanin (%) content in strawberry under pomegranate-based agroforestry system

Planting condition / Treatment	Anthocyanin (%)		
	S_1 (Closed)	S_2 (Open)	Mean
T_1 (Control)	1.23	0.42	**0.82^{gh}**
T_2 (Bamboo mulch alone)	1.65	1.44	**1.54^{de}**
T_3 (Bamboo mulch + Natural farming)	3.06	1.84	**2.45^{a}**
T_4 (Bamboo mulch+ RDF)	1.32	1.13	**1.22^{f}**
T_5 (Bamboo mulch+ FYM)	2.30	1.54	**1.92^{bc}**
T_6 (Pine mulch alone)	1.10	0.71	**0.90^{g}**
T_7 (Pine mulch+ Natural farming)	2.58	1.94	**2.26^{a}**
T_8 (Pine mulch+ RDF)	1.60	1.26	**1.43^{def}**
T_9 (Pine mulch+ FYM)	0.59	0.55	**0.57^{h}**
T_{10} (Poplar mulch alone)	2.51	1.92	**2.21^{a}**
T_{11} (Poplar mulch + Natural farming)	1.83	1.58	**1.70^{cd}**
T_{12} (Poplar mulch+ RDF)	1.47	1.09	**1.28^{ef}**
T_{13} (Poplar mulch+ FYM)	2.53	1.86	**2.19^{ab}**
Mean	**1.83**	**1.33**	
$CD_{(0.05)}$ **T** 0.28 **S** 0.11 **T × S** 0.39			

The quality parameters of fruit increased with use of inorganic manures along with the application of mulched plots than plots with no manure and no mulch. Quality traits of strawberry are associated with weed free conditions, maximum moisture conservation and uptake of nutrients. Thus, organic mulch kept soil moist during summers which enhanced water content.

The increase in quality traits of strawberry might be due to the larger size of plant leaves which increases photosynthetic activities resulting in more production of carbohydrates.

The important constituent of chlorophyll is nitrogen which was provided readily by the NPK to the plants at initial stages which accumulates more photosynthates and carbohydrates are formed which ultimately results in maximum total soluble solids. Which is clear from the result of the present investigation i.e., more the total soluble solids more is the total sugars and less is the titratable acidity.

The results of the present investigation are in conformity with the results of Kaur and Mirza (2018); Skupien and Oszmianski (2004); Moor *et al*. (2004).

4.3 PHYSICO-CHEMICAL PROPERTIES OF SOIL UNDER AGROFORESTRY SYSTEM AND SOLE CROPPING

4.3.1 pH

The data regarding the effect of mulches and manures on pH under strawberry under wild pomegranate-based agroforestry system had been recorded and presented in Table 24.

It can be deduced from the data represented in Table 24 that manures and mulches showed significant effect on pH. The maximum (7.05) pH was recorded in treatment T_{12}, which was statistically at par with T_{13}, T_{10}, T_5, T_3, T_4, T_2, T_7, T_6. Minimum pH (6.26) was recorded in treatment T_8.

Table 24. Effect of different mulch and manures on soil pH after harvest of strawberry under wild pomegranate-based agroforestry system

Treatment / Planting condition	pH		
	S_1 (Canopy)	S_2 (Open)	Mean
T_1 (Control)	6.85	6.58	**6.72^{bc}**
T_2 (Bamboo mulch alone)	7.06	6.70	**6.88^{abc}**
T_3 (Bamboo mulch + Natural farming)	7.15	6.75	**6.95^{abc}**
T_4 (Bamboo mulch+ RDF)	7.03	6.85	**6.94^{abc}**
T_5 (Bamboo mulch+ FYM)	7.12	6.81	**6.96^{ab}**
T_6 (Pine mulch alone)	6.92	6.64	**6.78^{abc}**
T_7 (Pine mulch+ Natural farming)	6.87	6.69	**6.78^{abc}**
T_8 (Pine mulch+ RDF)	6.16	6.35	**6.26^{e}**
T_9 (Pine mulch+ FYM)	6.45	6.26	**6.35^{de}**
T_{10} (Poplar mulch alone)	7.09	6.91	**6.99^{ab}**
T_{11} (Poplar mulch + Natural farming)	6.53	6.74	**6.63^{cd}**
T_{12} (Poplar mulch+ RDF)	7.17	6.94	**7.05^{a}**
T_{13} (Poplar mulch+ FYM)	7.10	6.97	**7.03^{ab}**
Mean	**6.88^{x}**	**6.71^{y}**	
$CD_{(0.05)}$ **T** 0.33 **S** 0.13 **T × S** NS			

The planting conditions had significant effect on pH, as maximum pH (6.88) was recorded under S_1 (agroforestry system) and the minimum pH (6.71) was recorded in S_2 (open condition).

The combined effect of planting condition and treatment (T×S) showed non-significant effect on pH.

4.3.2 Electrical conductivity (dS m^{-1})

The data regarding the effect of mulches, manures and planting condition showed significant effect on electrical conductivity.

The data presented in Table 25 revealed that maximum (0.36 dS m^{-1}) EC was observed in treatment T_{11} which is statistically at par with T_{12}. Minimum EC (0.26 dS m^{-1}) was found in treatment T_1 (Control).

Table 25. Effect of mulch and manures on soil EC (dSm^{-1}) after harvest of strawberry under wild pomegranate-based agroforestry system

Treatment / Planting condition	EC (dS m^{-1})		
	S_1 (Canopy)	**S_2 (Open)**	**Mean**
T_1 (Control)	0.30	0.22	**0.26^{g}**
T_2 (Bamboo mulch alone)	0.34	0.23	**0.29^{ef}**
T_3 (Bamboo mulch + Natural farming)	0.32	0.24	**0.28^{fg}**
T_4 (Bamboo mulch+ RDF)	0.36	0.25	**0.31^{cde}**
T_5 (Bamboo mulch+ FYM)	0.35	0.26	**0.30^{cdef}**
T_6 (Pine mulch alone)	0.33	0.27	**0.30^{def}**
T_7 (Pine mulch+ Natural farming)	0.28	0.28	**0.28^{fg}**
T_8 (Pine mulch+ RDF)	0.36	0.29	**0.33^{bc}**
T_9 (Pine mulch+ FYM)	0.34	0.30	**0.32^{cd}**
T_{10} (Poplar mulch alone)	0.35	0.28	**0.31^{cd}**
T_{11} (Poplar mulch + Natural farming)	0.43	0.29	**0.36^{a}**
T_{12} (Poplar mulch+ RDF)	0.38	0.31	**0.35^{ab}**
T_{13} (Poplar mulch+ FYM)	0.34	0.27	**0.31^{cdef}**
Mean	**0.34^{x}**	**0.27^{y}**	
$CD_{(0.05)}$			
T 0.02			
S 0.01			
T × S 0.32			

The planting conditions had significant effect on EC, as maximum EC (0.34 dS m^{-1}) was recorded under S_1 (agroforestry system) and the minimum EC (0.27 dS m^{-1}) was recorded in S_2 (open condition).

The combined effect of treatment and planting condition (T×S) showed significant effect on EC. Maximum EC (0.43 dS m^{-1}) was recorded in treatment combination $T_{11}S_1$ and minimum (0.22 dS m^{-1}) was recorded in T_1S_2.

4.3.3 Available nitrogen (Kg ha^{-1})

The data regarding the effect of mulches, manures and planting conditions on available nitrogen under wild pomegranate-based agroforestry system had been recorded and presented in Table 26.

A glance at Table 26 shows that planting condition had significant effect on available nitrogen under wild pomegranate-based agroforestry system. The maximum (337.53 kg ha^{-1}) was recorded under S_1 (agroforestry system) and minimum (323.18 kg ha^{-1}) available nitrogen was in S_2 (open condition).

Table 26. Effect of mulch and manures on available soil nitrogen (kg ha^{-1}) after harvest of strawberry under wild pomegranate-based agroforestry system

Treatment / Planting condition	Available Nitrogen (kg ha^{-1})		
	S_1 (Canopy)	S_2 (Open)	Mean
T_1 (Control)	326.82	310.23	**318.52^{h}**
T_2 (Bamboo mulch alone)	332.92	322.07	**327.50^{fg}**
T_3 (Bamboo mulch + Natural farming)	330.67	324.53	**327.60^{fg}**
T_4 (Bamboo mulch+ RDF)	340.39	323.40	**331.89^{cd}**
T_5 (Bamboo mulch+ FYM)	340.81	323.33	**332.07^{c}**
T_6 (Pine mulch alone)	330.23	322.10	**326.16^{g}**
T_7 (Pine mulch+ Natural farming)	332.24	324.30	**328.27^{ef}**
T_8 (Pine mulch+ RDF)	345.12	326.55	**335.83^{b}**
T_9 (Pine mulch+ FYM)	342.86	325.37	**334.11^{b}**
T_{10} (Poplar mulch alone)	336.55	321.92	**329.24^{ef}**
T_{11} (Poplar mulch + Natural farming)	336.27	323.54	**329.90^{de}**
T_{12} (Poplar mulch+ RDF)	343.99	325.92	**334.95^{b}**
T_{13} (Poplar mulch+ FYM)	348.97	328.13	**338.55^{a}**
Mean	**337.53^{x}**	**323.18^{y}**	
$CD_{(0.05)}$ **T** 2.01 **S** 0.79 **T × S** 2.85			

The mulches and manures had significant effect on nitrogen, as maximum available nitrogen (338.55 kg ha^{-1}) was recorded in treatment T_{13} and the minimum available nitrogen (318.52 kg ha^{-}) was recorded in treatment T_1.

The combined effect of treatment and planting conditions (T×S) showed significant effect on available nitrogen. Maximum available nitrogen (348.97 kg ha^{-1}) was found in treatment combination $T_{13}S_1$ and minimum (310.23 kg ha^{-1}) was found in T_1S_2.

4.3.5 Available phosphorus (Kg ha^{-1})

The data regarding the effect of mulches, manures and planting conditions on available phosphorus under wild pomegranate-based agroforestry system had been recorded and presented in Table 27.

The inquisition of the data presented in Table 27 revealed that treatment shows significant effect on available phosphorus under wild pomegranate-based agroforestry system. The maximum (60.68 kg ha^{-1}) available phosphorus was recorded in treatment T_{12}, which was statistically at similar with T_4, T_8. Minimum available phosphorus (48.69 kg ha^{-1}) was recorded in treatment T_1 (Control).

Table 27. Effect of different mulch and manures on available soil phosphorus (kg ha^{-1}) after harvest of strawberry under wild pomegranate-based agroforestry system

Planting condition / Treatment	Available Phosphorus (kg ha^{-1})		
	S_1 (Canopy)	S_2 (Open)	Mean
T_1 (Control)	48.92	48.56	**48.69^{g}**
T_2 (Bamboo mulch alone)	54.88	51.61	**53.24^{ef}**
T_3 (Bamboo mulch + Natural farming)	58.58	53.82	**56.20^{cde}**
T_4 (Bamboo mulch+ RDF)	61.57	56.90	**59.23^{ab}**
T_5 (Bamboo mulch+ FYM)	53.22	52.15	**52.68^{f}**
T_6 (Pine mulch alone)	53.73	52.45	**53.09^{f}**
T_7 (Pine mulch+ Natural farming)	56.03	54.28	**55.15^{def}**
T_8 (Pine mulch+ RDF)	64.29	52.49	**58.39^{abc}**
T_9 (Pine mulch+ FYM)	55.59	57.98	**56.79^{bcd}**
T_{10} (Poplar mulch alone)	53.50	52.02	**52.76^{f}**
T_{11} (Poplar mulch + Natural farming)	58.94	55.74	**57.34^{bcd}**
T_{12} (Poplar mulch+ RDF)	65.93	55.43	**60.68^{a}**
T_{13} (Poplar mulch+ FYM)	59.82	54.03	**56.92^{bcd}**
Mean	**57.31^{x}**	**53.64^{y}**	
$CD_{(0.05)}$ **T** 3.01 **S** 1.18 **T × S** 4.26			

The planting conditions had significant effect on soil moisture, as maximum available phosphorus (57.31 kg ha^{-1}) was recorded under S_1 (agroforestry system) and the minimum available phosphorus (53.64 kg ha^{-1}) was recorded in S_2 (open condition).

The combined effect of the treatment and planting condition (T×S) showed significant effect on available phosphorus. Maximum available phosphorus (65.93 kg ha^{-1}) was recorded in treatment combination $T_{12}S_1$, which is significantly at par with T_8S_1 and minimum (48.56 kg ha^{-1}) was recorded T_1S_2.

4.3.4 Available potassium (kg ha^{-1})

The data regarding the effect of mulches and manures on available potassium under wild pomegranate-based agroforestry system had been recorded and presented in Table 28.

Table 28. Effect of different mulch and manures on available soil potassium (kg ha^{-1}) after harvest of strawberry under wild pomegranate-based agroforestry system

Planting condition / Treatment	Available Potassium (kg ha^{-1}) S_1 (Canopy)	S_2 (Open)	Mean
T_1 (Control)	252.53	228.74	**240.63^f**
T_2 (Bamboo mulch alone)	273.93	240.14	**257.03^e**
T_3 (Bamboo mulch + Natural farming)	279.80	251.17	**265.48^{de}**
T_4 (Bamboo mulch+ RDF)	318.43	295.28	**306.85^a**
T_5 (Bamboo mulch+ FYM)	293.78	252.92	**273.35^{bcd}**
T_6 (Pine mulch alone)	284.58	240.68	**262.63^{de}**
T_7 (Pine mulch+ Natural farming)	270.28	264.05	**267.16^{cde}**
T_8 (Pine mulch+ RDF)	321.72	241.12	**281.42^{bc}**
T_9 (Pine mulch+ FYM)	280.72	244.63	**264.68^{de}**
T_{10} (Poplar mulch alone)	275.02	244.20	**259.61^{de}**
T_{11} (Poplar mulch + Natural farming)	299.62	274.92	**287.27^b**
T_{12} (Poplar mulch+ RDF)	338.03	303.69	**320.89^a**
T_{13} (Poplar mulch+ FYM)	288.13	235.14	**261.69^{de}**
Mean	**290.50^x**	**255.44^y**	
$CD_{(0.05)}$ **T** 14.72 **S** 5.77 **T × S** 20.81			

It can be deduced from the data presented in Table 28 revealed that mulches and treatment had significant effect on available potassium under wild pomegranate-based agroforestry system. The maximum (320.89 kg ha^{-1}) was recorded in treatment T_{12} which was statistically at similar with T_4. Minimum available potassium (240.63 kg ha^{-1}) was observed in treatment T_1 (Control).

The planting conditions had significant effect on potassium, as maximum available potassium (290.50 kg ha^{-1}) was recorded under S_1 (agroforestry system) and the minimum available potassium (255.44 kg ha^{-1}) was recorded in S_2 (open condition).

The combined effect of treatment and planting condition (T×S) showed significant effect on potassium. Maximum available potassium (338.03 kg ha^{-1}) was found in treatment combination $T_{12}S_1$, which is significantly at par with T_8S_1 and T_4S_1 and minimum (228.74 kg ha^{-1}) was found in T_1S_2.

4.3.6 Soil moisture (%)

The data garnered in Table 29 revealed that the planting condition shows significant effect on soil moisture under wild pomegranate-based agroforestry system.

Table 29. Effect of different mulch and manures on soil moisture (%) after harvest of strawberry under based agroforestry system

Planting condition / Treatment	Soil moisture (%)		
	S_1 (Canopy)	S_2 (Open)	Mean
T_1 (Control)	9.83	9.22	**9.52^{c}**
T_2 (Bamboo mulch alone)	10.69	9.88	**10.28^{bc}**
T_3 (Bamboo mulch + Natural farming)	10.12	9.46	**9.79^{c}**
T_4 (Bamboo mulch+ RDF)	10.72	9.39	**10.05^{bc}**
T_5 (Bamboo mulch+ FYM)	12.42	10.52	**11.47^{bc}**
T_6 (Pine mulch alone)	9.96	9.54	**9.75^{ab}**
T_7 (Pine mulch+ Natural farming)	10.23	9.35	**9.79^{a}**
T_8 (Pine mulch+ RDF)	10.32	9.70	**10.01^{c}**
T_9 (Pine mulch+ FYM)	12.29	11.20	**11.75^{a}**
T_{10} (Poplar mulch alone)	10.15	9.58	**9.86^{c}**
T_{11} (Poplar mulch + Natural farming)	10.37	9.91	**10.14^{bc}**
T_{12} (Poplar mulch+ RDF)	11.11	9.40	**10.25^{c}**
T_{13} (Poplar mulch+ FYM)	11.32	10.49	**10.91^{c}**
Mean	**10.73^{x}**	**9.82^{y}**	
$CD_{(0.05)}$ **T** 0.90 **S** 0.35 **T × S** NS			

The maximum (11.75 %) soil moisture was recorded in treatment T_9. Minimum (9.52 %) soil moisture was recorded in treatment T_1 (Control).

The planting conditions had significant effect on soil moisture, as maximum soil moisture (10.73 %) was recorded under S_1 (agroforestry system) and the minimum soil moisture (9.82 %) was recorded under S_2 (open condition).

The combined effect of planting condition and treatment (T×S) showed non-significant effect on soil moisture.

4.3.7 Organic carbon (%)

The data regarding the effect of mulches and manures on organic carbon under wild pomegranate-based agroforestry system had been recorded and presented in Table 30.

Table 30. Effect of different mulch and manures on soil organic carbon (%) after harvest of strawberry under wild pomegranate-based agroforestry system

Treatment / Planting condition	Organic carbon (%)		
	S_1 (Canopy)	S_2 (Open)	Mean
T_1 (Control)	0.67	0.61	**0.64^{d}**
T_2 (Bamboo mulch alone)	0.68	0.66	**0.67^{cd}**
T_3 (Bamboo mulch + Natural farming)	0.70	0.65	**0.68^{cd}**
T_4 (Bamboo mulch+ RDF)	0.74	0.67	**0.71^{cd}**
T_5 (Bamboo mulch+ FYM)	0.70	0.66	**0.68^{cd}**
T_6 (Pine mulch alone)	0.72	0.69	**0.71^{cd}**
T_7 (Pine mulch+ Natural farming)	0.94	0.86	**0.90^{a}**
T_8 (Pine mulch+ RDF)	0.89	0.85	**0.87^{ab}**
T_9 (Pine mulch+ FYM)	0.92	0.82	**0.87^{ab}**
T_{10} (Poplar mulch alone)	0.71	0.67	**0.69^{cd}**
T_{11} (Poplar mulch + Natural farming)	0.85	0.79	**0.82^{b}**
T_{12} (Poplar mulch+ RDF)	0.75	0.67	**0.71^{c}**
T_{13} (Poplar mulch+ FYM)	0.98	0.84	**0.91^{a}**
Mean	**0.79^{x}**	**0.73^{y}**	
$CD_{(0.05)}$			
T 0.06			
S 0.02			
T × S NS			

Critical examination of the data presented in Table 30 revealed that mulches, manures and planting condition have significant effect on organic carbon content under wild pomegranate-based agroforestry system. Among treatment maximum (0.91 %) organic carbon was recorded in treatment T_{13}, which was statistically at par with T_7, T_9, T_8. Minimum organic carbon (0.64 %) was recorded in treatment T_1(Control).

The planting conditions had significant effect on organic carbon, as maximum organic carbon (0.79 %) was recorded under S_1 (agroforestry system) and the minimum organic carbon (0.72 %) was recorded in S_2 (open condition).

The combined effect of planting condition and treatment (T×S) showed non-significant effect on organic carbon.

The results of the present investigation revealed that available N, P and K were recorded higher in the agroforestry system as compared to the open condition this may be due to the more organic decomposition in the agroforestry system due to the addition of the leaf litter in the system. The results of the resent investigation can also be supported with the findings of (Anon., 1995) where he reported that planting trees on field boundaries increased organic carbon by 24.9%, available nitrogen by 29.6%, available phosphorus by 65.6% and potash by 44.4%

Agroforestry is a man-made ecosystem which allow the maximum possible utilization of the land through introduction of various field crops under trees while upholding soil fertility. Tree canopy reduces soil and water erosion by reducing the rainfall velocity of the rain drops and also lowers the maximum temperature. The organic carbon in soil is improved though leaf litter from trees. The shedding of leaves of tree in agroforestry might increase the organic carbon content in the top surface layer of soil which results in increase in the fertility of soil and ultimately enhances the productivity of strawberry plants intercropped under agroforestry system. Mulch and organic manures might increase the concentrations of elements like nitrogen, phosphorus, potassium and organic carbon which ultimately resulted in the increase fertility of soil. The leaf litter on the floor adds organic matter through the decomposition of leaves, litter fall at fine root turn over may have increase soil organic matter concentration. The addition of mulches to the crop, increases soil organic matter that leads to important increase in soil water retention capacity providing good environment for soil microbes and plant nutrients during its decomposition. The soil organic carbon content may have increased from the addition of various mulches which resulted in the improvement of habitat of soil organism and the incorporation of organic and inorganic sources might have increased microbial activity for microorganisms beneath the mulch material which ultimately have enhanced nitrification process. Breakdown of organic mulches under favourable water and temperature conditions may release nutrients into the soil for roots to uptake and for microbial utilization.

Similar results are in accordance with the findings of Bowen et al. (1988); Gupta *et al*. (2009); Wang *et al*. (2022); Alemu (2015); Jamir and Dutt (2020); Chalker-Scott (2007); Kumar *et al*. (2014)

4.4 CHANGE IN SOIL PHYSICO-CHEMICAL PROPERTIES

4.4.1 Soil pH

Data represented in Table 31 depicts that different treatment displayed significant variation in soil pH. The pH increased under all the mulch treatments.

4.4.2 Electrical conductivity (dS m^{-1})

The glance at the Table 31 revealed that the electrical conductivity was significantly influenced. It was increased in all the treatments.

4.4.3 Soil Organic Carbon (%)

It was evident from the data presented in Table 31 that different treatment had significant effect on organic carbon. All the mulch treatments significantly enhanced the soc with maximum enhancement witnessed in

4.4.4 Available Nitrogen (Kg ha^{-1})

The perusal of the data presented in Table 31 that different treatment showed significant effect on available nitrogen. Available nitrogen depicted increasing trend in all the treatments where T_4 denoted the highest increase.

4.4.5 Available phosphorus (Kg ha^{-1})

The data displayed in Table 31 that different treatment confirmed the significant effect on available potassium. It increased under all treatments except T_1. Maximum increase was observed under the treatment

4.4.6 Available potassium (Kg ha^{-1})

It can be deduced from the data presented in Table 31 that different treatment showed significant effect where all treatments displayed positive effect. Maximum positive effect was noted in T_{12}.

4.4.7 Soil moisture (%)

The data demonstrated that different treatment showed significant variation in soil moisture.

Table 31. Effect of different mulch and manures on change in soil physico-chemical properties under strawberry-wild pomegranate-based agroforestry system

	pH	EC (dS $^{m-1}$)	OC (%)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	SM (%)
Planting condition							
AFS (S_1)	(+)0.39	(+)0.34	(+)0.10	(+)12.35	(+)5.79	(+)50.51	(+)2.45
Sole cropping (S_2)	(+)0.05	(+)0.27	(+)0.11	(+)14.97	(+)4.44	(+)20.96	(+)1.98
$CD_{(0.05)}$	NS	0.01	NS	0.79	5.79	5.79	0.35
T_1 (control)	(+)0.14	(+)0.26	(-)0.01	(+)1.83	(-)1.67	(+)3.40	(+)1.46
T_2 (Bamboo mulch alone)	(+)0.31	(+)0.29	(+)0.02	(+)10.80	(+)2.88	(+)19.80	(+)2.22
T_3 (Bamboo mulch+ Natural farming)	(+)0.37	(+)0.28	(+)0.02	(+)10.90	(+)5.84	(+)28.25	(+)1.73
T_4 (Bamboo mulch+ RDF)	(+)0.37	(+)0.31	(+)0.05	(+)15.20	(+)8.87	(+)69.62	(+)1.99
T_5 (Bamboo mulch+ FYM)	(+)0.39	(+)0.30	(+)0.03	(+)15.38	(+)2.32	(+)36.11	(+)2.19
T_6 (Pine mulch alone)	(+)0.20	(+)0.30	(+)0.05	(+)9.47	(+)2.73	(+)25.39	(+)2.85
T_7 (Pine mulch+ Natural farming)	(+)0.21	(+)0.28	(+)0.22	(+)11.57	(+)4.79	(+)29.93	(+)3.69
T_8 (Pine mulch+ RDF)	(-)0.32	(+)0.32	(+)0.21	(+)19.14	(+)8.03	(+)44.18	(+)1.95
T_9 (Pine mulch+ FYM)	(-)0.22	(+)0.32	(+)0.22	(+)17.42	(+)6.43	(+)27.44	(+)3.41
T_{10} (Poplar mulch alone)	(+)0.42	(+)0.31	(+)0.04	(+)12.54	(+)2.40	(+)22.37	(+)1.80
T_{11}(Poplar mulch + Natural farming)	(+)0.06	(+)0.36	(+)0.17	(+)13.21	(+)6.98	(+)50.03	(+)2.08
T_{12} (Poplar mulch+ RDF)	(+)0.48	(+)0.34	(+)0.06	(+)18.26	(+)10.32	(+)83.63	(+)1.69
T_{13} (Poplar mulch+ FYM)	(+)0.61	(+)0.31	(+)0.26	(+)21.86	(+)6.56	(+)24.40	(+)1.73
$CD_{(0.05)}$ T	0.33	0.02	0.06	2.02	3.02	14.76	0.90
$CD_{(0.05)}$ S×T	NS	0.03	NS	2.85	4.27	20.87	NS

The results are in harmony with the results of Sirohi and Bangara (2017) who reported increase in the available N, P and K from initial values of soil than in sole cropping. Sarvade *et al*. (2014) showed improvement in soil physico-chemical properties viz. electrical conductivity, available N, P and K.

4.5 CORRELATION BETWEEN GROWTH, YIELD AND SOIL PARAMETERS OF FRAGARIA× ANNANASA

Correlation is a statistical tool for evaluating the degree and magnitude of relationship between different traits. Karl Pearson's coefficient of correlation was calculated between growth, yield and soil parameters of strawberry under wild pomegranate-based agroforestry system.

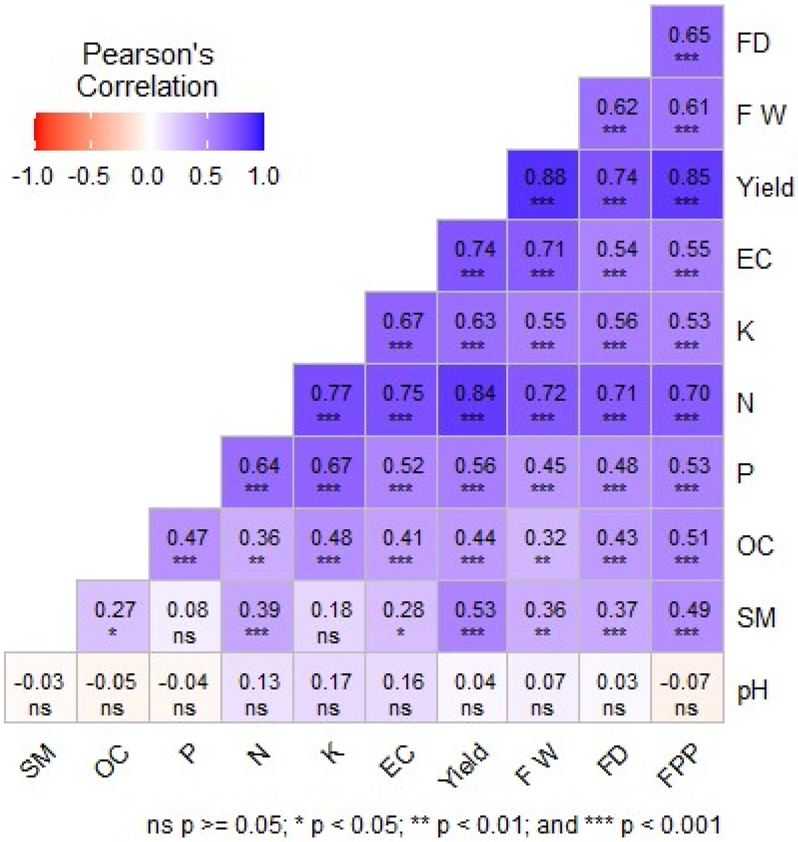

Fig 3. Correlation between growth, yield and soil parameters

Whereas; FPP= fruit per plant, FD= fruit diameter(mm), FW= fruit weight(g), pH= soil pH, EC= Electrical conductivity (dS m^{-1}), OC= Organic carbon (%), SM= Soil moisture, N= Available N (kg ha^{-1}), P= Available P (kg ha^{-1}), K= Available K (kg ha^{-1})

Data in Fig. 3 shows the correlation between pH and yield was non-significant as pH did not affect the yield significantly while correlation of yield between other parameters viz. soil moisture, organic carbon, potassium, phosphorus, nitrogen, electrical conductivity, fruit weight, fruit diameter and fruit per plant were found to be significant. Considering fruit parameters, positive correlation was witnessed with yield and soil parameters except soil pH. Effect of soil moisture showed non-significant relationship with phosphorus and potassium whereas all other parameters were positively correlated.

The results of the present investigation are in line with the findings of Manito *et al.* (2019); Jagdamma *et al.* (2008); Kumar *et al.* (2019) registered similar results which displayed significant relationship between growth, yield and soil parameters.

4.6 BIO-ECONOMIC ANALYSIS

The economics of Wild pomegranate-based agroforestry system consist of fruit crop as intercrop was calculated and Cost of cultivation, Gross returns, Net returns and Benefit cost ratio of strawberry were determined in the presence as well as absence of Wild pomegranate to know the profitability of systems.

4.6.1 Cost of cultivation (Rs/ha)

The data regarding the effect of mulches and manures on cost of cultivation of strawberry under wild pomegranate-based agroforestry system had been recorded and presented in Table 32.

The total cost of cultivation of strawberry under wild pomegranate-based agroforestry system and total cost of cultivation in open condition was calculated and presented in Table 32. Among different manures and mulches treatments highest cost of cultivation (Rs 413797.69 lakh ha^{-1}) was calculated for S_1T_9 and minimum (Rs 216412.83 lakh ha^{-1}) in S_2T_1 (control). Maximum cost of cultivation can be accounted for higher cost of farmyard manure.

Table 32. Effect of mulches and manures on cost of cultivation in strawberry under pomegranate-based agroforestry system

Treatment	Cost of cultivation (Rs/ha)	
	S_1 (canopy)	S_2 (open)
T_1 (Control)	240222.69	216412.83
T_2 (Bamboo mulch alone)	270432.69	246622.83
T_3 (Bamboo mulch + Natural farming)	275732.69	251922.83
T_4 (Bamboo mulch+ RDF)	277216.69	253406.83
T_5 (Bamboo mulch+ FYM)	411412.69	387602.83
T_6 (Pine mulch alone)	272817.69	249007.83
T_7 (Pine mulch+ Natural farming)	278117.69	254307.83
T_8 (Pine mulch+ RDF)	279601.69	255791.83
T_9 (Pine mulch+ FYM)	413797.69	389987.83
T_{10} (Poplar mulch alone)	262482.69	238672.83
T_{11} (Poplar mulch + Natural farming)	267782.69	243972.83
T_{12} (Poplar mulch+ RDF)	269266.69	245456.83
T_{13} (Poplar mulch+ FYM)	403462.69	379652.83

4.6.2 Gross Returns (Rs/ha)

The data regarding the effect of mulches and manures on gross return of strawberry under wild pomegranate-based agroforestry system had been recorded and presented in Table 33.

The gross returns from strawberry under wild pomegranate-based agroforestry system and gross returns in open condition was calculated and presented in Table 33. Among different manures and mulches treatments highest gross return (Rs 1093104.82 ha^{-1}) was obtained from S_1T_9 (Pine mulch+ FYM) and lowest gross return (Rs 235996.10 ha^{-1}) was observed in S_2T_1 (Control).

Table 33. Effect of mulches and manures on gross returns in strawberry under pomegranate-based agroforestry system

Treatment	Gross returns (Rs/ha)	
	S_1	S_2
T_1 (Control)	608778.82	235996.10
T_2 (Bamboo mulch alone)	872631.03	484357.00
T_3 (Bamboo mulch + Natural farming)	925929.08	512561.90
T_4 (Bamboo mulch+ RDF)	906006.92	570390.80
T_5 (Bamboo mulch+ FYM)	884640.58	537234.00
T_6 (Pine mulch alone)	850096.56	575510.60
T_7 (Pine mulch+ Natural farming)	936030.47	597696.40
T_8 (Pine mulch+ RDF)	1088994.50	614592.20
T_9 (Pine mulch+ FYM)	1093104.82	619505.00
T_{10} (Poplar mulch alone)	792223.86	491901.00
T_{11} (Poplar mulch + Natural farming)	966047.18	498067.30
T_{12} (Poplar mulch+ RDF)	916305.06	479481.00
T_{13} (Poplar mulch+ FYM)	857201.27	455303.40

4.6.3 Net returns (Rs/ha)

The data regarding the effect of mulches and manures on net returns from strawberry under wild pomegranate-based agroforestry system had been recorded and presented in Table 34.

The net returns from strawberry under wild pomegranate-based agroforestry system and net returns in open condition was calculated and presented in Table 34. Among different manures and mulches treatments highest (Rs 809392.81ha^{-1}) net return was obtained from S_1T_8 (Pine mulch+ RDF) and lowest (Rs 19583.27ha^{-1}) net returns were observed in S_2T_1 (Control).

Table 34. Effect of mulches and manures on net returns in strawberry under pomegranate-based agroforestry system

Treatment	Net returns (Rs/ha)	
	S_1	S_2
T_1 (Control)	368556.13	19583.27
T_2 (Bamboo mulch alone)	602198.34	237734.17
T_3 (Bamboo mulch + Natural farming)	650196.40	260639.07
T_4 (Bamboo mulch+ RDF)	628790.23	316983.97
T_5 (Bamboo mulch+ FYM)	473227.89	149631.17
T_6 (Pine mulch alone)	577278.87	326502.77
T_7 (Pine mulch+ Natural farming)	657912.78	343388.57
T_8 (Pine mulch+ RDF)	809392.81	358800.37
T_9 (Pine mulch+ FYM)	679307.13	229517.17
T_{10} (Poplar mulch alone)	529741.18	253228.17
T_{11} (Poplar mulch + Natural farming)	698264.49	254094.47
T_{12} (Poplar mulch+ RDF)	647038.37	234024.17
T_{13} (Poplar mulch+ FYM)	453738.58	75650.57

4.6.4 Benefit: cost ratio

The data regarding the effect of mulches and manures on benefit cost ratio of strawberry under wild pomegranate-based agroforestry system had been recorded and presented in Table 35.

Table 35. Effect of mulches and manures on B:C in strawberry under pomegranate-based agroforestry system

Treatment	B:C	
	S_1	S_2
T_1 (Control)	2.53	1.09
T_2 (Bamboo mulch alone)	3.23	1.96
T_3 (Bamboo mulch +Natural farming)	3.36	2.03
T_4 (Bamboo mulch+ RDF)	3.27	2.25
T_5 (Bamboo mulch+ FYM)	2.15	1.39
T_6 (Pine mulch alone)	3.12	2.31
T_7 (Pine mulch+ Natural farming)	3.37	2.35
T_8 (Pine mulch+ RDF)	3.89	2.40
T_9 (Pine mulch+ FYM)	2.64	1.59
T_{10} (Poplar mulch alone)	3.02	2.06
T_{11} (Poplar mulch + Natural farming)	3.61	2.04
T_{12} (Poplar mulch+ RDF)	3.40	1.95
T_{13} (Poplar mulch+ FYM)	2.12	1.20

The benefit cost ratio from strawberry under wild pomegranate-based agroforestry system and benefit cost ratio in open condition was calculated and presented in Table 35. Among different manures and mulches treatments highest benefit cost ratio showed that highest benefit cost ratio (3.89) was obtained from S_1T_8 (Pine mulch + RDF) and lowest benefit cost ratio (1.09) was observed in S_2T_1.

The organic mulches and manures are easily available at affordable prices, and mulches being biodegradable in nature supports bio-health of soil and leads to sustainable development. The use of non-biodegradable plastic mulch not only reduce aeration but also adulterates the quality of soil. The maximum net returns were reported when strawberry was intercropped under wild pomegranate-based agroforestry system than sole cropping. The plausible reason for this might be due to the shade provided by the tree and the great retention of soil moisture by organic mulches. Maximum gross returns were obtained from plots mulched with pine needles along with farm yard manure. Highest benefit cost ratio was observed under agroforestry system than in open condition.

Similar results were reported by Dutt and Thakur (2004), Meena (2015), Ashok *et al.* (2016) Verma *et al.* (2002) and Nayak et al. (2014) that agroforestry system gave higher net returns under agroforestry system compared to sole cropping.

Chapter-5

SUMMARY AND CONCLUSION

The present investigation entitled **"Effect of different farming practices and mulches on production of strawberry under wild pomegranate-based agroforestry systems"** was carried out in the Experimental farm Pandah and laboratory of Department of Silviculture and Agroforestry and Department of Fruit Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, during the years 2022-23.

The study was conducted to ascertain the effect of different farming practices and mulches on growth, development and yield of strawberry, physico-chemical properties of soil and economic appraisal of agroforestry system along with sole cropping of strawberry. The experiment was laid out in a randomized block design (RBD) with three replications and thirteen treatments: T_1(Control without any fertilizers and mulches); T_2 (Bamboo mulch alone); T_3 (Bamboo mulch+ Natural farming); T_4 (Bamboo mulch + RDF); T_5 (Bamboo mulch + FYM); T_6 (Pine mulch alone); T_7 (Pine mulch+ Natural farming); T_8 (Pine mulch + RDF); T_9 (Pine mulch + FYM); T_{10} (Poplar mulch alone); T_{11} (Poplar mulch + Natural farming); T_{12} (Poplar mulch+ RDF); T_{13} (Poplar mulch +FYM). The results obtained during this research have been summarized here under the following heads and sub-heads:

5.1 Effect of manures and mulches on production of strawberry under wild pomegranate-based agroforestry-based system.
5.2 Performance of strawberry under agroforestry system.
5.3 Correlation between yield, quality of strawberry.
5.4 To study the effect of manures and mulches on the nutrient status of soil.
5.5 To calculate the bio-economic appraisal of the fruit-based agroforestry system.

5.1 EFFECT OF MANURES AND MULCHES ON PRODUCTION OF STRAWBERRY UNDER WILD POMEGRANATE-BASED AGROFORESTRY-BASED SYSTEM

The vegetative and cropping parameters like plant height, plant spread, leaf area, number of leaves per plant, total chlorophyll content, number of flowers, fruit set and number of fruits was significantly affected by both organic and inorganic manures. Amongst manures and mulches, inorganic manure along with application of pine mulch enhanced plant spread, number of leaves, number of leaves, fruit set, number of fruits. The maximum yield (361.48 g/plant) was recorded with application of pine mulch along with farm yard manure. Strawberry plants performed better under agroforestry system than in sole cropping.

5.2 GROWTH PARAMETER OF WILD POMEGRANATE

The parameters of wild pomegranate such as height, crown spread, light transmission ratio and fruit yield indicates that intercropping was influenced by tree parameters substantially. Therefore, these parameters were observed to know about the influence of wild pomegranate on strawberry plants.

5.3 CORRELATION BETWEEN GROWTH, YIELD AND SOIL PARAMETERS OF STRAWBERRY

It is a measure of statistical accuracy that expresses how closely two variables are connected linearly. Correlation was done between growth, yield and soil parameters, where results revealed that growth characters of strawberry i.e., Fruit per plant, fruit diameter and fruit weight were highly correlated.

5.4 TO STUDY THE EFFECT OF MANURES AND MULCHES ON THE NUTRIENT STATUS OF SOIL

The physical and chemical properties of soil like moisture (%), pH, EC, organic carbon, available N, P and K were higher with the application of poplar along with inorganic manure under wild pomegranate-based agroforestry system than in sole cropping and control. It was observed that with the application of poplar mulch there was an increase in pH, EC, organic carbon, available potassium and available phosphorus.

5.5 TO CALCULATE THE BIO-ECONOMIC APPRAISAL OF THE FRUIT-BASED AGROFORESTRY SYSTEM.

The results with regard to the effect of different farming practices and mulches on cost of cultivation, gross returns, net returns and benefit-cost ratio for the cultivation of strawberry under wild pomegranate-based agroforestry system revealed that, growing strawberry under Wild pomegranate-based agroforestry system is profitable. The gross return (Rs 1093104.82 ha^{-1}), net return (Rs 809392.81 ha^{-1}) and B:C ratio (3.89) was reported higher under wild pomegranate-based agroforestry system, whereas, the gross return (Rs 235996.10 ha^{-1}), net return (Rs 19583.27 ha^{-1}) and B:C ratio (1.09) were recorded minimum under sole cropping. When compared the economics of agroforestry system and sole cropping of strawberry, agroforestry system was found to me be more financially worthwhile.

CONCLUSION

- The results demonstrated that application of organic manure boosted growth and yield of strawberry plants.
- The results displayed positive correlation between parameters of plants i.e., growth and yield parameters.
- The application of mulch protected soil moisture and improved the nutrient status of soil under wild pomegranate agroforestry system.
- The use of organic and inorganic manures illustrated to be much more efficient than no manures in control.
- The economic parameters were observed higher under wild pomegranate-based agroforestry system than in sole cropping.
- It has been confirmed that strawberry can be cultivated under wild pomegranate effectively and will increase socio-economic condition of the farmers as there is no other fresh fruit is available in the market.

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APPENDIX-1

Analysis of variance of growth, yield and biological parameters of strawberry under wild pomegranate tree.

Source of variation	df	Mean Sum of Squares							
		Plant height	Plant spread	Leaf area	Number of leaves	TCC	Number of flowers	Fruit set	Fruit per plant
Replication	2	0.06	0.79	617.10	2.63	4.44	12.42	177.63	2.87
Treatment (T)	12	2.53	10.45	42.80	42.85	63.50	30.81	54.63	43.70
Planting condition (S)	1	306.63	2245.37	12969.10	1640.56	377.27	991.53	473.64	192.28
Interaction(T×S)	12	1.92	5.56	19.60	5.55	7.20	30.81	45.15	2.59
Error	50	0.30	1.84	54.30	2.84	4.62	2.36	29.01	1.14

Source of variation	df	Mean Sum of Squares							
		Yield per plant	Yield ton per ha	Fruit length	Fruit diameter	Fruit weight	TSS	Titratable acidity	TSS per acid
Replication	2	1023	0.56	1.15	27.35	1.70	0.63	0.00013	1.73
Treatment (T)	12	13402	8.11	17.58	15.68	2.48	0.90	0.0002	86.39
Planting condition (S)	1	182564	251.38	702.42	528.07	141.02	1.23	0.0175	26.19
Interaction(T×S)	12	1130	0.77	3.54	3.14	1.74	0.02	0.00022	0.895
Error	50	721	0.43	7.05	6.07	1.10	0.09	0.000235	2.397

Source of variation	df	Mean Sum of Squares			
		Total sugars	Reducing sugar	Non-reducing	Anthocyanin
Replication	2	0.03	0.05	0.004	0.02
Treatment (T)	12	0.29	0.33	0.073	2.21
Planting condition (S)	1	71.92	60.39	1.206	4.87
Interaction(T×S)	12	0.12	0.20	0.093	0.16
Error	50	0.10	0.10	0.064	0.06

APPENDIX-II

Analysis of variance for soil parameters under different mulch and manures influenced by wild pomegranate tree

Source of variation	df	Mean Sum of Squares						
		pH	EC	N	P	K	SM	SOC
Replication	2	0.13	0.00053	7.40	17.69	661.60	1.55	0.001
Treatment (T)	12	0.38	0.00464	158.50	64.78	2794.80	2.81	0.059
Planting condition (S)	1	0.62	0.11309	4010.50	261.84	23980.00	16.23	0.079
Interaction(T×S)	12	0.05	0.00197	33.40	23.46	473.10	0.33	0.001
Error	50	0.08	0.00039	3.00	0.74	161.10	0.59	0.003

APPENDIX –III

Cost of cultivation and returns of wild pomegranate

Sr. No.	Items	Unit	Qty	Unit Rate	Total
1.	Site preparation	Mandays	10	100	1000
2.	Digging of pits	Mandays	13	100	1300
3.	Planting and filling of pits	Mandays	12	100	1200
4.	Cost of seedling	Seedlings	1250	30	37500
5.	Cost of FYM	Kg	700	2.58	1806
					42806
					4699.87
6.	Weeding	Mandays	25	300	7500
7.	Pruning	Mandays	20	350	7000
					19199.87
8.	Miscellaneous (2% on total working capital)	Rs.			383.99
9.	Interest on working capital (5%)	Rs.			959.99
10.	Land rent	Rs.			3200
11.	Depreciation and maintenance	Rs.			66
	Total cost of cultivation	Rs.			**23809.86**
	Returns				
	Fruit yield from anardana (kg/ tree)	Rs/kg	187.5	300	**56250**

APPENDIX- IV

Sr. No.	Items	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	T_{13}
1	Field preparation													
	3 ploughing @ Rs 2000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000
	Preparation of beds and channels 20man days @ Rs 400/day	8000	8000	8000	8000	8000	8000	8000	8000	8000	8000	8000	8000	8000
2	Seed and seed sowing													
	Seed cost for one hectare 33,333 runner/ha @ Rs 4/runner	1,33,333	1,33,333	1,33,333	1,33,333	1,33,333	1,33,333	1,33,333	1,33,333	1,33,333	1,33,333	1,33,333	1,33,333	1,33,333
	Seed preparation and sowing 25man days @ Rs 400/day	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
3	Manures and fertilizers													
	CAN 80kg @ Rs 20/kg	0	0	0	1600	0	0	0	1600	0	0	0	1600	0
	SSP 40kg @ Rs 10/kg	0	0	0	400	0	0	0	400	0	0	0	400	0
	MOP 40 kg @ Rs 10/kg	0	0	0	400	0	0	0	400	0	0	0	400	0
	FYM 50000 kg @ Rs 2.58/kg	0	0	0	0	129000	0	0	0	129000	0	0	0	129000
	Jeevamrut 500 @ Rs 2/lt	0	0	1000	0	0	0	1000	0	0	0	1000	0	0
	Labour charges for application of fym 10-man days @ Rs 400/day	0	0	0	0	4000	0	0	0	4000	0	0	0	4000

	Labour charges for application of jeevamrut 10man days @ Rs 400/day	0	0	4000	0	0	0	4000	0	0	0	4000	0	0
	Labour charges for application of fertilizers 10man days @ Rs 400/day	0	0	0	4000	0	0	0	4000	0	0	0	4000	0
4	Mulching													
	dry leaves of bamboo mulch 15000 kg/ha @ Rs 1.50/kg	0	22500	22500	22500	22500	0	0	0	0	0	0	0	0
	dry leaves of pine mulch 15000 kg/ha @ Rs 1.65/kg	0	0	0	0	0	24750	24750	24750	24750	0	0	0	0
	dry leaves of poplar mulch 15000 kg/ha @ Rs 1.00 /kg	0	0	0	0	0	0	0	0	0	15000	15000	15000	15000
	Application of mulch 15man days @ Rs 400/day	0	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000
5	Intercultural operations													
	Two weeding and earthing up 30man days @ Rs 400/day	12000	12000	12000	12000	12000	12000	12000	12000	12000	12000	12000	12000	12000
6	Irrigation													
	Irrigation 25man days @ Rs 400/ha	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
7	Harvesting													
	10man days for first harvesting @ Rs 400/day	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
	10man days for	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000

	second harvesting @ Rs 400/day													
	10man days for third harvesting @ Rs 400/day	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
8	Transportation @ Rs 2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
	Sub-total (Rs/ha)	**193833.3**	**222333.3**	**227333.3**	**228733.3**	**355333.3**	**224583.3**	**229583.3**	**230983.3**	**357583.3**	**214833.3**	**219833.3**	**221233.3**	**347833.3**
9	Miscellaneous cost (2% of sub-total) (Rs/ha)	3876.7	4446.7	4546.7	4574.7	7106.7	4491.7	4591.7	4619.7	7151.7	4296.7	4396.7	4424.7	6956.7
10	Interest on working capital (4% of sub-total) (Rs/ha)	7753.3	8893.3	9093.3	9149.3	14213.3	8983.3	9183.3	9239.3	14303.3	8593.3	8793.3	8849.3	13913.3
	Total Variable Cost (Rs/ha)	205463.3	235673.3	240973.3	242457.3	375553.3	238058.3	243358.3	244842.3	375858.3	227723.3	233023.3	234507.3	368703.3
11	**Fixed cost**													
	Land rent (Rs/ha)	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
	Depreciation (Rs/ha)	250	250	250	250	250	250	250	250	250	250	250	250	250
	Land revenue (Rs/ha)	31.25	31.25	31.25	31.25	31.25	31.25	31.25	31.25	31.25	31.25	31.25	31.25	31.25
	sub- total (Rs/ha)	10281.25	10281.25	10281.25	10281.25	10281.25	10281.25	10281.25	10281.25	10281.25	10281.25	10281.25	10281.25	10281.25
12	Interest on fixed capital (6.5% of sub-total) (Rs/ha)	668.28	668.28	668.28	668.28	668.28	668.28	668.28	668.28	668.28	668.28	668.28	668.28	668.28
	Total fixed cost (Rs/ha)	10949.53	10949.53	10949.53	10949.53	10949.53	10949.53	10949.53	10949.53	10949.53	10949.53	10949.53	10949.53	10949.53
	Total (Rs/ha)	**216412.83**	**246622.83**	**251923**	**253407**	**387602.83**	**249007.83**	**254308**	**2555792**	**389988**	**238673**	**243973**	**245457**	**379653**

Sale Rate of Strawberry: Rs 92 per kg

DR YS PARMAR UNIVERSITY OF HORTICULTURE AND FORESTRY
NAUNI- 173230, SOLAN (HP)
DEPARTMENT OF SILVICULTURE AND AGROFORESTRY

Title of Thesis	:	**"Effect of different farming practices and mulches on production of strawberry under wild pomegranate-based agroforestry systems"**
Name of the Student	:	Anshul Thakur
Major field	:	Silviculture and Agroforestry
Minor field	:	i) Forest Products and Utilization ii) Forest Biology and Tree Improvement
Year of award of Degree	:	2023
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Major advisor	:	Dr. Prem Prakash

ABSTRACT

The present investigation entitled "Effect of different farming practices and mulches on production of strawberry under wild pomegranate-based agroforestry systems" was carried out at the experimental farm Pandah of Department of of Silviculture and Agroforestry, Dr Y S Parmar University of Horticulture and Nauni, Solan, Himachal Pradesh, during the year 2022-2023. The experiment was laid out in RBD (2 factorial) with three replications comprising of three organic mulchesand three manures with 13 Treatments viz., T_1 (Control), T_2 (Bamboo mulch alone), T_3 (Bamboo mulch + Natural farming), T_4 (Bamboo mulch+ RDF), T_5 (Bamboo mulch+ FYM), T_6 (Pine mulch alone), T_7 (Pine mulch+ Natural farming), T_8 (Pine mulch+ RDF), T_9 (Pine mulch+ FYM), T_{10} (Poplar mulch alone), T_{11} (Poplar mulch + Natural farming), T_{12} (Poplar mulch+ RDF) and T_{13} (Poplar mulch+ FYM).Treatments mulched with pine needles along with organic manures showed best results in most of the growth and yield parameters of strawberry. Based on the findings yield of strawberry was recorded best in treatment (T_9) which was mulched with pine needles along with farm yard manure under wild pomegranate, displayed better results for yield parameters for strawberry than for sole cropping. Soil physico-chemical properties like pH, OC, moisture, available nitrogen, available phosphorus and available potassium were higher in poplar mulch along with inorganic manures. The integration of strawberry under agroforestry will provide multi-products to the farmers which will increase the socio-economic status of the farmers.

Signature of the student	**Signature of Major Advisor**
Name: Anshul Thakur	**Name: Dr. Prem Prakash**
Dated:	**Date:**

Professor and Head
Department of Silviculture and Agroforestry

BRIEF BIO-DATA

Name : **Anshul Thakur**

Father's Name : Sh. Kuldeep Kumar

Mother's Name : Smt. Reeta Devi

Date of Birth : 24-04-2000

Sex : Female

Marital status : Unmarried

Nationality : Indian

Permanent Address : C/o MR Garg Niwas, Village Dhainda, Post Office Totu, Tehsil & Distt. Shimla (HP) 171 011

ACADEMIC QUALIFICATION:

Examination Passed	Year of Passing	University/Board	Division	OGPA (% equivalent)
Matriculation	2015	CBSE	First	7.80
10+2	2017	CBSE	First	8.04
Graduation	2021	DR YSP UHF Nauni	First	7.36

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(Anshul Thakur)