EFFECTS OF ORGANIC MANURES ON GROWTH, YIELD AND OIL QUALITY PARAMETERS OF LEMON GRASS UNDER WILD POMEGRANATE BASED AGROFORESTRY SYSTEM

Thesis

by

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CERTIFICATE - I

This is to certify that the thesis titled **"Effects of organic manures on growth, yield and oil quality parameters of lemon grass under wild pomegranate based agroforestry system"** submitted in partial fulfilment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY (FORESTRY)** in the discipline of **AGROFORESTRY** of Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP)- 173230 is a bonafide research work carried out by **Ms. Mitali Mehta (F-2019-04-D)** daughter of **Shri Hukam Chand** under my supervision. No part of this thesis has been submitted for any other degree or diploma.

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

Place: Nauni, Solan
Dated:_____

(Dr. K S Pant)
Major Advisor

CERTIFICATE-II

This is certified that the thesis titled **"Effects of organic manures on growth, yield and oil quality parameters of lemon grass under wild pomegranate based agroforestry system"** submitted by **Ms. Mitali Mehta (F-2019-04-D)** daughter of **Shri Hukam Chand** to the Dr. Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (HP)-173230 India in partial fulfilment of the requirement for the degree of **DOCTOR OF PHILOSOPHY (FORESTRY)** in the discipline of **AGROFORESTRY** has been approved by Advisory Committee after the thesis viva-voice examination of the student in collaboration with an External Examiner.

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Place: Nauni, Solan
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CONTENTS

ABBREVIATIONS USED

%	:	Per cent
@	:	At the rate
°C	:	Degrees Celsius
AFS	:	Agroforestry system
BCR	:	Benefit cost ratio
BD	:	Bulk Density
CD	:	Critical Difference
cfu/g	:	Colony-forming unit per gram
cm	:	Centimetre
cm^2	:	Square centimetre
cmol	:	Centimoles
dSm^{-1}	:	Deci Siemens per meter
E.M.	:	Effective microorganisms
EC	:	Electrical Conductivity
et al.	:	Etalia (Co-workers)
etc	:	Et Cetera
FYM	:	Farm Yard Manure
$gI_2/100g$	:	Grams of iodine per 100 grams
ha^{-1}	:	Per hectare
i.e.	:	That is
K	:	Potassium
Kg	:	Kilogram
l/ha	:	Litre per hectare
m	:	Metre
m^2	:	Square metre
m^3	:	Cubic metre
Mg	:	Megagram
mg KOH/g	:	Milligrams of potassium hydroxide
mm	:	Millimeter
MOP	:	Muriate of potash
ms/cm	:	Milli Siemens per centimetre
N	:	Nitrogen
P	:	Phosphorus
pH	:	Power of hydrogen
RBD	:	Randomized Block Design
RDF	:	Recommended dose of fertilizers
RDN	:	Recommended dose of nitrogen
Rs	:	Rupees
SOC	:	Soil Organic Carbon
sq m	:	Square metre
t	:	Tonnes
t/ha	:	Tonnes per hectare
TSP	:	Triple super phosphate
TSS	:	Total soluble solids
viz.	:	Videlicet (namely)

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Chapter-1

INTRODUCTION

Sustainability in agricultural production systems along with the food and nutritional security are major challenges due to climate change, increasing population pressure and over exploitation of natural resources (Castle *et al.,* 2022, Silva *et al*., 2022). The farmers are heavily burdened through high cost of inputs, increased severity of insect-pests and diseases, natural vagaries and uncertain market prices for the agricultural produce. India, being the most populated country in the world, consists of about 17 per cent world's human population and 15 per cent of livestock population supported only on 2.4 per cent geographical area, which is very bleak to support such a huge population. Since, land holdings are shrinking due to population growth, there is a tremendous pressure on the earth's finite natural resources to meet the demands of an expanding population. There is a need for integrated systems like agroforestry because there is no room for horizontal land expansion. According to International Centre for Research in Agroforestry (ICRAF), the term agroforestry can be defined as "a land use system that integrates trees with agricultural crops and/or animals, simultaneously or sequentially, to get higher productivity, more economic returns, better social and ecological benefits on a sustained yield basis, than are obtainable from monoculture on the same unit of land, especially under conditions of low levels of technological inputs and on marginal sites" (Cialdella *et al*., 2023).

Agroforestry systems are deliberately designed to maximize the positive interactions between tree and non-tree components encompassing a wide range of practices (Dutta *et al*., 2023). The fundamental idea behind the practice of agroforestry is that the trees are integral part of natural ecosystems providing a range of benefits in the agricultural domain (Dutta *et al*., 2023, Castle *et al*., 2022, Murthy *et al*., 2016). Agroforestry provides a unique opportunity to combine the alike objectives of climate change adaptation and biodiversity conservation. It has the ability to enhance the resilience of the system for coping with the adverse impacts of climate change. Although agroforestry systems are not primarily designed for carbon sequestration, but there are many recent studies that substantiate the evidence that agroforestry systems can play a major role in storing carbon in aboveground as well as below ground biomass in the form of root, necromass and soil organic carbon (Jesus *et al*., 2023, Murthy *et al*., 2016).

Agroforestry meets almost half of the demand of fuelwood, 65 per cent (small timber), 70–80 per cent (wood for plywood), 60 per cent (raw material for paper pulp) and 9–11 per cent (green fodder requirement of livestock), in addition to its environmental benefits (NRCAF, 2013). In 2050, requirement of fodder will be increasing by 1.5 times, food grain and fuel wood by two times and timber by three times (CAFRI, 2015). According to the most recent figures, agricultural development is responsible for about 90 per cent of global deforestation. This change in land use is a reaction to a number of underlying factors, such as poverty, unsustainable production and consumption patterns (FAO and UNEP, 2022). Agroforestry has the potential to meet the demand for food, fodder, firewood and timber, against the continuous shrinkage of land and water resources and the threat of changing climate in future. According to National Agroforestry Policy 2014, there is insufficient research on agroforestry models suitable for the diverse agro-climatic regions, for the indigenous and multi-purpose species or on domestication of species, resulting in over emphasis on few species like Poplar, Eucalyptus, Kadam etc. (GOI, 2014). Therefore, there is need to study other species growing naturally in any area for agroforestry systems.

Wild pomegranate (*Punica granatum* L.) is an emerging wild fruit of Central Asia that belongs to the genus Prunus and the family Punicaceae. The pomegranate is native to the area, growing as a wild shrub from northern India to Iran, amid the mid-hill belts of the states of Himachal Pradesh, Uttarakhand and Jammu and Kashmir in India. Wild pomegranate is widely dispersed in the drier and submarginal outer Himalaya at an elevation 900 to 1800 metres above mean sea level (Thakur *et al*., 2011). It is found in several districts of the Himachal Pradesh namely Solan, Sirmaur, Shimla, Mandi, Kullu, and Chamba (Bhrot, 1998). The wild pomegranate is an important fruit crop of the mid hills of the Himalayas with various types of phytonutrients in the form of anthocyanins, flavonoids, and phenolics that impart antioxidant properties in addition to colour (Sharma and Thakur, 2016). This has led to an increase in demand for its value-added products in recent years. Given the nutritional and nutraceutical benefits of wild pomegranates, industrialising them into a variety of commercially processed products is essential for meeting the nutritional needs of people in developing countries, especially since they are a more affordable source of bioactive ingredients than those from pomegranates that have been cultivated.

Utilisation of medicinal and aromatic plants (MAPs) dates back to the dawn of humanity (Tilaye *et al*., 2018). In the last twenty years, a resurgence in interest in medicinal and aromatic plants has created booming markets and manufacturing potential for many plant species. Medicinal and aromatic plants are getting attention across the globe, because they offer a wide range of safe and affordable, preventive and corrective therapies, which are useful for health (Suresh *et al*., 2012). These plants and their products not only serve as a vital source of income for small holders and entrepreneurs but also enable the country to earn foreign exchange by way of export. India is the second-largest exporter of medicinal plants after China (Lakshmi and Sekhar, 2018).

Medicinal and aromatic plants play a significant role in rural economy of Himachal Pradesh. Out of hundred most important medicinal plant species traded in the nation, twenty-four are found in the state. The state exports 2,500 tonnes of medicinal plants and their economic parts. The legal annual trade of medicinal plants in the state is worth about Rs.10 crore at current market prices. The state government earns about Rs 40 lakh per annum from export permits for medicinal plants. Realizing the importance of medicinal and aromatic plants, the state government is providing impetus to the cultivation of these plants to make Himachal, a 'Herbal State' of the country (Guleria *et al*., 2014).

Cymbopogon (family Poaceae) is an important grass having about 120 species which grows in tropical and subtropical regions all over the world. This genus is known to contain roughly 140 species, 45 of which have been documented from India. Lemongrass grows in compact clumps that can reach a height of 1.8 m, a width of 1.2 m, with a short rhizome. The leaves of lemongrass are 0.9 m long, 1.3-2.5 cm wide and have drooping tips (Ravinder *et al*., 2010). The *Cymbopogon* species produce essential oils rich in monoterpenes such as citral, citronellol, citronellal, elemol, 1,8-cineole, linalool, limonene, geraniol, β-carophyllene, geranyl acetate, geranyl formate and methyl heptanone (Dutta *et al.,* 2014). *Cymbopogan* due to its commercially valuable essential oils is ranked among the top ten oil bearing crops in the world.

The essential oils of lemongrass are widely used in pharmaceutical, cosmetics, food and flavour, agriculture industries and possess an array of medicinal uses. The plant possesses strong lemony odour due to its high content of the aldehyde citral, which has two geometric isomers, geranial (citral a) and neral (citral b) (Premathilake *et al.,* 2018). It contains 1-2 per cent of essential oil on dry basis and the chemical composition of essential oil is varying widely upon habitat, genetic diversity and agronomic practices (Paviani *et al*., 2006).

Recently, crop yields in the majority of agrarian nations have been static or decreasing (Paramesh *et al.,* 2023). The long-term use of inorganic fertilizers without organic supplement have damaged the soil physical, chemical and biological properties leading to environmental pollution (Albiach *et al.,* 2000). Additionally, the excessive cost for other inputs, a lack of technical expertise, credit constraints and the availability of the wrong type of fertilizer at the wrong time has worse consequences. According to recent reports, the Indian fertilizer market reached $887 billion and is projected to increase by 5.5 % by 2026 (IFA, 2020). The agriculture causes rise in global greenhouse gas emissions, which is mostly attributable to the use of synthetic fertilizers and pesticides. The careless use of fertilizers, particularly nitrogen, is one of the main contributors to environmental contamination (Davidson *et al*., 2014). Thus, organic farming is not only the paradigm for sustainable agriculture and food security, but smart combinations of organic and conventional methods, that could contribute toward productivity increases in global agriculture. Organic food is gaining popularity throughout the world. The growing demand is mainly attributable to consumer concerns about negative implications of conventional agriculture for human health and the environment. Million hectares of previously fertile land have become unsuitable for agricultural production because of soil degradation, often as a result of mismanagement (Quandt, 2021, Meemken *et al*., 2018). Organic farming has grown the best possible relationship between the earth and human being. Soil organic matter content is the direct measure of soil fertility.

Organic farming system emphasises on the use of organic matters for maintaining soil health, growth and multiplication of beneficial microbes and minimizing health hazards associated with food (Quandt, 2021, Santoro *et al.,* 2020). Medicinal and aromatic plants perform better in terms of yield and quality under organic farming system. At present, the imbalanced application of chemical fertilizer caused decreases in the quality of products not only inferior but also in residual effect lead to enter the food chain and threat to human health and other creatures (Liu *et al.,* 2019*,* Badalingappanavar *et al.,* 2018). This scenario has encouraged scientists towards using organic manures for improving soil properties and profitable crop production.

In today's intensive agriculture systems, no single source of plant nutrients, including chemical fertilizers, organic manures, crop residues, and bio-fertilizers, can supply all the nutrients, a crop requires (Mahajan and Gupta, 2009). Thus, there is need to maintain the balance between the use of organic manure and inorganic fertilizers in order to sustain crop production without deteriorating soil fertility. Integrated nutrient management by combining chemical fertilizers with animal manures, compost and green manures, encompasses effective and prudent supply, usage and supervision of all the major elements of plant nutrient resources (Meena and Reddy, 2021). It can also lower overall costs, improve the physiochemical conditions of the soil and the environment, remove economic obstacles, protect the soil nutrient balance and find safe ways to dispose of agricultural waste (Selim, 2019). Integrating all potential nutrient sources not only increases crop productivity but also improves the soil resource base (Nath *et al*., 2018). Therefore, to restore sustainable soil health without reducing production potential, integrated nutrient management practices must be implemented.

Agroforestry systems, especially fruit-based can be viable option to intercrop medicinal and aromatic plants. Keeping the facts in view, the present study "**Effects of organic manures on growth, yield and oil quality parameters of lemon grass under wild pomegranate based agroforestry system**" has been finalized with the following objectives:

1. To study the effect of organic manures on growth, yield and oil quality parameters of lemon grass.
2. To assess the effect of organic manures on soil physico-chemical properties.
3. Bio-economic appraisal of wild pomegranate based agroforestry.

Chapter-2

REVIEW OF LITERATURE

The appurtenant review of literature on the subject of "**Effects of organic manures on growth, yield and oil quality parameters of lemon grass under wild pomegranate based agroforestry system**" is being presented below under the following headings:

2.1 Effect of organic manures on growth, yield and oil quality parameters of lemongrass

2.2 Effect of organic manures on soil physico-chemical properties

2.3 Bio-economic appraisal of wild pomegranate-based agroforestry

2.1 EFFECT OF ORGANIC MANURES ON GROWTH, YIELD AND OIL QUALITY PARAMETRES OF LEMONGRASS

In the Organic Farm of CSK, Palampur, Himachal Pradesh, India, Punam *et al*. (2012) conducted an experiment to assess the impact of various organic management treatments on the production and quality of lemon grass (*Cymbopogon citratus*). Organic inputs (*viz*., farm yard manure (FYM); vermicompost; agnihotra ash; and neem powder) were added at the time of planting, while Bt + Himbio and the biodynamic preparation (BD 500) were sprayed regularly at one-month intervals. Crops were sown on dates matching moon and non-moon position according to the Biodynamic planting calendar. They found that the addition of agnihotra ash along with sowing as per moon position resulted in a higher yield of lemon grass (+124 %, +99 %) and a higher oil per cent (+155 %, +144 %) over the control, in biennial study.

Shahi *et al*. (2012) conducted an experiment to evaluate the effect of different nutrient sources on lemongrass in Uttar Pradesh. The experiment included five treatments namely, T_1: 100 % NPK as RDF, T_2: 50 % NPK + 5t FYM ha^{-1}, T_3: Green leaf manuring 10 t ha^{-1} +10 t FYM, T_4: 100 % N through vermicompost and T_5: 100 % N through poultry manure. The results revealed that 100 % N application through poultry manure produced the highest herbage yield compared to the other treatments i.e., RDF (40:60:40 kg/ha), 50 % NPK + FYM @ 5 t ha^{-1}, green leaf manuring @ 10 t ha^{-1} + FYM @ 10 t/ha and 100 % N through vermicompost.

Gajbhiye *et al*. (2013) examined the effect of FYM and NPK fertilizer on growth and quality parameters of lemongrass. The results of the study showed that all the growth parameters, herbage yield, dry matter yield of lemon grass increased with the application of 10 t FYM/ha and 120:60:60 kg NPK/ha. The oil content was superior with the application of 5 t FYM/ha and 60:30:30 kg NPK/ha, whereas 5 t FYM/ha and 90:45:45 kg NPK/ha recorded the highest oil yield.

Abdou *et al.* (2014) investigates the response of lemongrass to different levels of compost and biofertilizers. They reported that the plant height, number of tillers per plant, fresh and dry weights of leaves per feddan, essential oil per cent and yield per feddan, improved significantly due to the use of both low and high levels of compost, with the high level (8 ton/feddan) being much more effective. In the biofertilization and mineral treatments, both 100 % NPK and 75 % NPK + E.M. + yeast treatments were better than the other two treatments (75 % NPK + E.M. and 75 % NPK + yeast) in producing higher values of growth and essential oil parameters. Overall, the best results were obtained when lemongrass plants were supplied with compost at the level of 8 ton/feddan and fertilized with 75 % NPK combined with E.M. (effective microorganisms) and yeast.

Chinthapalli *et al.* (2015) carried out a comparative study on the effect of organic manures and inorganic fertilizers on the performance of Faba bean and pea applying organic manures as cow dung (15 t/ha) and inorganic fertilizer urea (120 kg/ha) and potassium chloride (125 kg/ha). The results revealed that application of cow dung showed significantly higher growth over the inorganic fertilizer in terms of germination percentage, fresh weight and dry weight, plant height, shoot length, and root length as well as number of leaves in both the legume plants. Likewise biochemical parameters have also shown significant differences from organic manures over the inorganic fertilizers and control. Thus, they concluded that in pea and Faba bean plants, organic fertilizer like cow dung produced better yield and quality grains.

Kumar *et al.* (2015) studied the effects of different combinations of vermicompost, farm yard manure, *Azospirillum* and RDF on coriander. They found that application of 25 % FYM (5 t ha $^{-1}$) + 75 % vermicompost (3.75 t ha^{-1}) recorded higher growth parameters (plant height, number of primary and secondary branches), quality (essential oil and moisture content in seeds) and yield (number of umbels per plant, number of umbellets per umbel, weight of seeds and yield) of coriander in comparison to other treatments.

Sahare and Mahapatra (2015) laid out an experiment to study the impact of organic manures on growth and yield of aerobic rice cultivation. They reported that application of combined organics EC (enriched compost 1/3) + VC (vermicompost 1/3) + GLM (green leaf manure 1/3) equivalent to RDF + FYM in combination with foliar application of jeevamrut @ 500 litre ha^{-1} at the time of planting, 30 and 60 days after sowing + panchgavya @ 5 % at panicle emergence and flowering stages recorded significantly higher growth parameters (plant height, number of tillers at harvest, total dry matter at harvest, panicle weight, panicle height and productive tillers per hill), higher grain yield and straw yield with high protein content in rice being at par with control.

Adhikari *et al.* (2016) conducted an experiment to study the effect of different organic manures on bell pepper and found that application of vermicompost significantly enhanced growth parameters (plant height, stem diameter, number of branches, average fruit weight) and yield parameters followed by poultry manure, farmyard manure, goat manure, chemical fertilizers and control.

Gerami *et al.* (2016) evaluated the effect of irrigation intervals and cattle manure levels on morphological traits, essential oil content and yield of oregano, at the experimental Farm, Urmia University, Iran under split-plots, arranged in randomized complete blocks with three replications consisting main plots carrying irrigation intervals (1, 2 and 3 weeks) and four levels of cattle manure at 0, 10, 20 and 30 t ha^{-1} as sub plots. The study recommended cultivation of oregano with three weeks irrigation intervals by use of 30 t ha^{-1} cattle manure as a good practice for achieving high essential oil content (2.07 %) and yield (66.62 kg ha^{-1}) in this region.

Chekolle *et al.* (2017) studied the synergic effect of organic manures and inorganic fertilizing system on grain yield of bread wheat consisting four level of N/P_2O_5 (0/0, 23/23, 46/46 and 69/69 kg ha^{-1}) and five level of farmyard manure (0, 4, 6, 8 and 10 t ha^{-1}) laid in factorial randomized complete block design with three replications. The study reported significant effect of organic and chemical fertilizer applications on grain yield. Where, highest grain yield (5.04 and 2.19 t ha^{-1}) with acceptable marginal rate of return (MRR=1228.9 and 2788.9 %) were obtained in the combined application of 46/46 N/P_20_5 kg ha^{-1} + 6 t ha^{-1} farmyard manure and 46/46 N/P_2O_5 kg ha^{-1} + 10 t ha^{-1} farmyard manure at Adi-golo and Mekan areas, respectively. In order to increase soil productivity and sustainably grow wheat, it is therefore more effective to use organic and chemical fertilizers together than separately.

Tripathi *et al.* (2017) evaluated the impact of different fertility levels for 2 years on the herbage and oil yield of lemongrass under irrigated conditions in Balrampur, Chhattisgarh. They tested five fertility levels *viz.*, $N_{75}P_{30}K_{30}$, $N_{100}P_{30}K_{30}$, $N_{125}P_{30}K_{30}$, $N_{75}P_{30}K_{30}$ + FYM @ 10 t ha^{-1} and FYM alone @ 25 t ha^{-1}. Three harvesting were taken in a year from June to February. The results showed that among two years, maximum herbage yield (976.05 q ha^{-1}) was recorded in first year which was 2 per cent higher than second year. Whereas, among different harvests, herbage yield was recorded maximum in second harvest (412.70 q ha^{-1}) during first year. Similarly, oil yield was maximum (553.59 kg ha^{-1}) in second year on application of 75 kg N + 30 kg P + 30 kg K + 10 t FYM ha^{-1}. They concluded that 75 kg N + 30 kg P + 30 kg K + 10 t FYM ha^{-1} was most suitable nutrient dose for enhancing the fresh herbage, oil yields and oil contents of lemongrass.

Potkile *et al.* (2017) reported that the application of jeevamrut along with vermicompost (@ 100 % RDN) significantly gave maximum growth and yield of soyabean and wheat in comparison to incorporation of organic manures (FYM, VC and compost) alone and along with jeevamrut, three crop residues (cotton, wheat and soyabean) @ 5 ton ha^{-1} along with jeevamrut.

El-Sayed *et al*. (2018) investigated the effect of NPK (recommended dose), biofertilizers (Nitrobien and Phosphorien) compost and poultry manure on growth, herb yield, essential oil production and anatomical structure of *Cymbopogon citratus* plants at the Department of Ornamental Horticulture, Cairo University, in Egypt during the two successive seasons of the year 2015 and 2016. The results revealed that the highest leaf area (83.99 cm^2) and number of tillers per plant (49.07) were obtained by the high rate of poultry treatment (15 ton/feddan) at the second cut in the second season. The poultry manure @ 10 ton/feddan resulted in the maximum total herb fresh yield (56.53 ton per feddan) and total herb dry yield (16.94 ton per feddan), in the second season. The production of essential oil per feddan during the first cut (in August) was more when compared to the second cut (in October) in both seasons. The highest oil yield per feddan was recorded in the second season with the application of poultry manure @ 10 ton/feddan at the first cut (82.26 l/feddan) and second cut (51.85 l/feddan), respectively. The anatomical structure such as thickness of the leaf sheath at the midrib region was superior when poultry manure was applied @ 10 ton/feddan. It was concluded that poultry manure was the best treatment for improving growth, yield and quality parameters of lemongrass.

Ganeshnauth *et al.* (2018) conducted an experiment to access the effect of vermicompost and other fertilizers on the growth and productivity of Pepper plants under five different treatments, namely T_1 (Promix), T_2 (vermicompost), T_3 (inorganic), T_4 (inorganic + vermicompost), and T_5 (control). The results revealed that T_3 (chemical fertilizer) has a significant effect on the growth of pepper plants producing plants with better height, stem diameter, number of leaves, branches, higher fruit diameter, fruit weight and fruit yield. They reported relatively high levels of pest and diseases in plants treated with chemical fertilizers, delayed flowering and fruiting period along with higher levels of leaf and fruit abscission compared with organic fertilizer (T_2).

Hameedi *et al.* (2018) studied the effect of organic nutrient sources on growth, yield and quality of bell pepper. Where, the results revealed application of vermicompost @ 7 t/ha + jeevamrut (drenching @ 5 % + foliar @ spray 3 %) significantly increased growth parameters (plant height, number of branches, leaf area index, number of fruits per plant) while on the other hand application of FYM @10 t/ha + VC 3.5 t/ha + jeevamrut (drenching @ 5 % + foliar spray @ 3 %) significantly increased yield and quality parameters (TSS and ascorbic acid content).

Muhammad *et al.* (2018) assessed the impact of organic and inorganic fertilizer on the growth and yield of sorghum in randomized complete block design with treatment consisting of three levels of cow manure (0, 1 and 2 ton/ha) and four levels of NPK 15:15:15 (0, 15, 30 and 45 kg/ha). The study revealed a significant difference among the various treatments used. Further, results showed that application of NPK fertilizer at the rate of 45 kg/ha and 2 ton/ha cow manure was significantly better in contrast to all other treatments.

Premathilake *et al.* (2018) investigated the effect of fertilizers on crop growth, biomass production, oil yield and chemical composition of lemongrass. The experiment consisted of four different treatments namely, F_1: compost only, F_2: inorganic fertilizer (urea, triple super phosphate and muriate of potash @ 278, 296 and 175 kg/ha respectively), F_3: inorganic fertilizer + Compost) and F_0: control (without fertilizer). Study revealed that maximum herbage yield (15.94 t ha^{-1}), dry matter yield (4.82 t ha^{-1}) and oil yield (fresh weight basis) (59.16 kg ha^{-1}) were recorded in the treatment of F_3 (Compost 106.5 g: Urea 2.96 g: TSP 3.15 g: MOP 1.86 g per plant). The major compounds identified in lemongrass oil were Citral, β- Citral, Geraniol, α Pinene and cis Verbenol.

Sharada and Sujathamma (2018) carried out an experiment to study the effect of organic manures and inorganic fertilizers on the quantitative and qualitative parameters of two cultivars of rice i.e., DRR Dhan 39 and RP.BIO.226 comprised of 12 treatments of four organic fertilizers as farmyard manure, vermicompost, panchagavya, jeevamrutha and inorganic fertilizers as combination of 60:75:75 levels of N, P and K. The results revealed that the variety DRR Dhan 39 gave the significant higher grain yield of 8713 kg/ ha and straw yield of 9483 kg/ha with 50 % organic fertilizers of vermicompost, jeevamrutha 5 % and panchagavya 3 % and 50 % inorganic fertilizer of NPK. Whereas, the variety of RP.BIO.226 recorded the highest grain yield of 6390 kg/ha with vermicompost, jeevamrutha 5 % and panchagvya 3 % (8 t/ha, foliar spray and 500 litres/ha) and highest straw yield of 7430 kg/ha with T_{10} treatment (50 % organic fertilizers of vermicompost, jeevamrutha 5 % and panchagavya 3 % and 50 % inorganic fertilizer of NPK).

Sondarva *et al*. (2018) assessed the effect of integrated nutrient management on brinjal (*Solanum melongena*) under teak based agroforestry system in South Gujarat. The experiment included fourteen treatments *viz.,* T_1: 100 % recommended dose of fertilizer (RDF - 100:50:50 NPK ha^{-1}), T_2: Azotobactor, T_3: Vermicompost, T_4: Neem cake, T_5: Bio-compost, T6: 50 % RDF + T_2, T_7: 50 % RDF + T_3, T_8: 50 % RDF + T_4, T_9: 50 % RDF + T_5, T_{10}: 75 % RDF + T_2, T_{11}: 75 % RDF + T_3, T_{12}: 75 % RDF + T_4, T_{13}: 75 % RDF + T_5 and T_{14}: 100 % RDF (100:50:50 NPK ha^{-1}) in open condition with three replications. The study revealed that maximum number of branches per plant (5.33), plant height (73.90 cm), number of fruits per plant (24.89) and yield (20357.35 kg ha^{-1}) of brinjal were observed under T_{14} treatment.

Abbas *et al*. (2019) evaluated the combined effect of compost, poultry manure and NPK fertilizers on yield of Okra. They found the application of organic fertilizers like poultry manure and compost as well as its mixture with full NPK considerably increase the growth and total yield attributes of Okra. On the other hand, the joint use of 50 % NPK + 50 % PM (poultry manure) exhibits the most significant impact on okra growth in contrast to all other treatments. They concluded that application of organic sources of fertilizers (i.e., poultry manure and compost) can improve the vegetable yield alone as well as in combination with NPK sources further ensuring less environmental pollution as well as enhancing the soil properties.

Aderounmu *et al*. (2019) assessed the effects of organic and inorganic fertilizers on the early growth and development of *Vitellaria paradoxa*. The experiment was laid out in completely randomized design; uniformly growing seedlings of 6-month-old in topsoil mixed with poultry droppings, cow dung, water hyacinth and NPK 15:15:15 fertilizer at 100 kg ha^{-1} and 200 kg ha^{-1} dosage levels, while untreated topsoil served as control. Increase in dosage levels of organic and inorganic fertilizers improved tree seedling performance. The results indicated that nutrients supply from NPK and organic manure enhanced growth performance of *Vitellaria paradoxa* seedlings. The study came to the conclusion that organic manure, which is readily available and environmentally acceptable, would also have a longer-lasting impact on the performance of seedlings and minimise soil toxicity.

Toungos (2019) evaluated the impact of organic manures and inorganic fertilizers on yield of Maize over four treatments *viz*., T_1: NPK 400 kg per ha, T_2: Organic (cow dung) 20 tons per ha, T_3: Combination (200 kg NPK and Cow dung 10 tons per ha) and T_4: Control under Randomized Block Design (RBD). He found that maximum height was obtained in plants applied with NPK, while control has the shortest plant. According to the study, application of NPK gives significantly higher yield and weight, shorter days to tasselling and silking in maize crop when compared to application of organic manure and control.

Nandapure *et al.* (2020) conducted an experiment to evaluate the influence of integrated nutrient management on growth parameters and herbage yield of Java Citronella. The experiment was planned in randomized block design with thirteen treatments consisting different combination FYM, NPK and FYM + NPK with three replications. They observed that the combined application of FYM + NPK @ 10 t + 140:40:80 kg ha^{-1} resulted in maximum number of tillers (58.43) and plant height (140.20 cm), followed by 5 t FYM + 140:40:80 kg NPK ha^{-1} which was significantly superior over rest of the treatments. They also recorded that herbage yield was comparatively higher during the second year and it increased successively with each combination of increasing FYM levels and NPK doses, which proves superiority of integrated nutrient management over sole application of organic manures and inorganic fertilizers.

Poonkodi *et al*. (2019) studied the effect of organic manures and inorganic fertilizers on the growth and yield of radish (*Raphanus sativus* L.) in Tamil Nadu. The experiment consisted of various combinations, inorganic fertilizers and organic manures such as farm yard manure, poultry manure and goat manure. The study revealed that integrated nutrient management i.e., the combined application of 75 per cent RDF + goat manure @ 2.5 tonnes ha^{-1} + poultry manure @ 2.5 tonnes ha^{-1} resulted in the maximum number of leaves $plant^{-1}$, leaf breadth, leaf length, tuber diameter, tuber length, tuber weight, and yield of radish.

Pramod *et al.* (2020) investigated the effect of organic manures and inorganic fertilizers on growth and yield parameters of sweet basil (*Ocimum basilicum* L.) consisting ten treatments of organic manures and inorganic fertilizers in combination and alone, in randomized block design. The results showed that highest number of primary branches per plant (21.11), number of leaves (1393), plant height (79.67 cm), fresh herbage yield (36.43 t/ha), dry herbage yield (7.54 t/ha) and oil yield (168.52 kg/ha) was recorded under treatment 50 % RDN through urea + 50 % RDN through poultry manure followed by 50 % RDN through urea + 50 % RDN through neem cake, respectively.

Tripathi *et al.* (2020) conducted a study to assess the effect of organic manures on the growth and yield of three medicinal plant species (*Andrographis paniculata, Withania somnifera and Ocimum sanctum)* in a peach-based agroforestry system. They observed that these three species could successfully be cultivated as intercrops under peach without any adverse impact on their performance and production ability. Growth and yield attributes of MAPs (Medicinal and aromatic plants) were higher when intercropped under peach than under sole cropping system. Results further revealed that the application of organic amendments had a significant effect on growth and yield of MAPs with superior performance at higher doses. The study focused on the opportunity for traditional farming communities in the Indian Himalayas to maximise land use effectiveness and minimise resource degradation by incorporating medicinal plants in current fruit-based agroforestry systems.

Akintola *et al.* (2021) studied the impact of organic manures and inorganic fertilizers on the growth of *Senecio biafrae*. The experiment comprised of seven treatments *viz*., T_0: control; T_1: top soil + 5 g of poultry manure; T_2: top soil + 10 g of poultry manure; T_3: top soil + 15 g of poultry manure; T_4: top soil + 5 g of NPK (15:15:15); T_5: top soil + 10 g of NPK (15:15:15) and T_6: top soil + 15 g of NPK (15:15:15). The study revealed that application of poultry and NPK fertilizer had significant effect on the height, leaf production and stem diameters of *S. biafrae*. The results further showed that *S. biafrae* responded well to the application of organic manure as compared to inorganic fertilizer and control treatment under study. Based on the study, they recommended the application of organic manure for maximum performance and growth of *S. biafrae* plant.

Massey *et al.* (2021) analysed the influence of organic manures and green manuring practices on growth, yield attributes, quality and economics of lemongrass under custard apple based agri-horti system. Four organic manures treatments namely, M_1-Vermicompost (2.5 t/ha), M_2-FYM (5.0 t/ha), M_3-Vermicompost (2.5 t/ha) + *Azotobacter*, and M_4-FYM (5.0

t/ha) + Vermicompost (2.5 t/ha) were allotted to main plot, four green manuring treatments *viz*. G_1-clusterbean, G_2-cowpea, G_3-Sunn hemp (*Crotalaria juncea*) and G_4-dhaincha as sub plot. The results revealed that vermicompost (2.5 t/ha) + *Azotobacter* treatment gave significantly higher results in terms of growth, yield, oil composition and quality along with improving soil nutrient composition.

Smitha *et al.* (2021) carried out an experiment to study the influence of organic nutrients on growth, yield and quality parameters of Brahmi (*Bacopa monnieri* L.). The experiment consisted of shade levels as the main plots (35 % shade, 50 % shade and 100 % sunlight) and nutrients requirement [50, 75 and 100 % N equivalent through FYM, 50, 75 and 100 % N equivalent through vermicompost, RDF (100:60:60 kg NPK/ha), RDF (100:60:60 kg NPK/ha) + FYM (10 t/ha)] as sub plots laid in strip plot design. They concluded that among different treatments, conjunctive use of recommended dose of fertilizers (100:60:60 kg NPK/ha) + FYM (10 t /ha) gave the highest dry herbage yield (16.35 t/ha) being statistically at par with other treatment combinations.

Attia *et al.* (2022) studied the impact of organic fertilizers on growth of marjoram plant under Siwa Oasis conditions consisting four treatments (T_1: control, T_2: 24 m^3 sheep manure/hectare, T_3: 24 m^3 compost manure/hectare and T_4: combination of 12 m^3 sheep manure and 12 m^3 compost manure/hectare). The results revealed that the soil amendment with sheep manure combined with compost was significantly superior to individual resources in improving growth and yield characteristics.

Toaima *et al*. (2022) conducted an experiment to evaluate the impact of organic manures on productivity of basil. The experiment was laid out in split plot design. The main plots included applying two compost manure levels before planting and subplots included cultivating five basil varieties (local and four foreign varieties: lime basil, smuglyanka basil, purple basil, and purple ruffles basil). The study revealed that applying compost manure at the highest level (48 m^3/hectare) significantly increased herb and oil yield attributes over the lowest level (24 m^3/hectare). The evaluation of varieties showed that the purple ruffles and purple varieties recorded the significantly higher herbage and oil yield. Further, they recommended applying 48 m^3 compost/hectare and cultivation of foreign purple variety to produce the best yield quality.

Zahid *et al.* (2022) studied the influence of organic and inorganic fertilizer application on growth patterns and antioxidants properties of Strawberry. The experiment comprised of different combinations of organic manures namely, farmyard manure (FYM), poultry manure (PM)) and inorganic (urea) (N 150 kg/ha) fertilizers. They discovered that strawberries produced the highest yield and higher-quality fruits when planted in soil that had been modified with a combined dose of FYM and PM totalling 75 kg N per ha. Similarly maximum survival percentage of 41 % and 28 % was recorded in the plants grown on soils amended with FYM equivalent to 75 kg N per ha + PM equivalent to 75 kg N per ha and FYM equivalent to 50 kg N per ha + PM equivalent to 50 kg N per ha + urea 50 kg N per ha compared to control.

2.2 THE EFFECT OF ORGANIC MANURES ON SOIL PHYSICO-CHEMICAL PROPERTIES

Manivannan *et al.* (2009) carried out a field experiment to evaluate the efficacy of vermicompost, in comparison to inorganic fertilizer on the biological, physical and chemical properties of soil along with growth, yield and nutrient content of bean. They found the application of vermicompost @ 5t ha^{-1} had reduced soil particle density, pH and electrical conductivity and increased organic carbon, micro nutrients and macronutrients as well as microbial activity, however the growth, yield and quality (protein and sugar content in seed) of bean were highest under the application of 50 % vermicompost + 50 % NPK.

Gopinath and Mina (2011) conducted an experiment at Almora to evaluate the effect of different organic manures (farmyard manure, poultry manure and vermicompost) and biofertilizers (*Rhizobium leguminosarum*) + phosphorus-solubilizing bacteria (*Pseudomonas sp.*) on soil properties under six treatments counting - T_1: farmyard manure @ 20 tonnes ha^{-1} + biofertilizers, T_2: poultry manure @ 5 tonnes ha^{-1} + biofertilizers, T_3: vermicompost @ 7.5 tonnes ha^{-1} + biofertilizers, T_4: farmyard manure @ 10 tonnes ha^{-1} + poultry manure and vermicompost each @ 1.5 tonnes ha^{-1} + biofertilizers, T_5: integrated nutrient management (farmyard manure @ 10 tonnes ha^{-1} + recommended NPK – 20:26:33 kg ha^{-1}) and T_6: control. They reported that treatment T_1 (farmyard manure 20 tonnes ha^{-1} + biofertilizers) resulted in the lowest soil bulk density (1.19 Mg m^{-3}) compared to other treatments, meanwhile pH increased in all the treatments compared to control. However, soil organic carbon was significantly higher in all the treatments (1.21–1.30 %) except in T_2 (poultry manure 5 tonnes ha^{-1} + biofertilizers) compared to control (1.06 %).

Suge *et al.* (2011) studied the effect of organic and inorganic sources of fertilizer on growth, yield and fruit quality of eggplant. The experiment was laid in split plot design with three replications. Two levels of mineral fertilizers treatments (50 % and 100 %) were randomized in main plots while three types of organic manures (FYM, Compost and Tithonia) and control treatments in the subplots. The results revealed that soil fertilized with 100 % recommended dose of NPK combined with organic manures produced the superior growth of plants and the highest amount of total fruit yields. They concluded that combination having 100 % of recommended NPK combined with farm yard manure was most promising and produced the best response.

Kannan *et al.* (2013) evaluated the effect of integrated nutrient management on soil fertility where, pore space was recorded maximum in integrated nutrient management practice including vermicompost and recommended dose of NPK. Particle density was recorded maximum in FYM treatments however, organic carbon was recoded highest in integrated nutrient management including vermicompost and recommended dose of NPK.

Shaikh *et al.* (2013) assessed the influence of organic and inorganic inputs on soil physical and chemical properties. The study showed that in organic inputs applied fields, there was significant increase in soil properties like organic carbon (0.11 % to 0.34 %), phosphorus (6.62 kg/ha to 15.16 kg/ha), water holding capacity (3.3 % to 8.5 %) over inorganic inputs applied fields, while decrease was recorded in pH (0.79 to 1.23) and electrical conductivity (0.07 ms/cm to 0.36 ms/cm) of soil in organic field compared to inorganic field. Meanwhile, potassium content was higher in both fields. Overall results showed that application of organic inputs like farm yard manure, Beejamruth and Jeevamruth significantly improves soil nutrient properties which results in increase in fertility and productivity of soil for sustainable development.

Tadesse *et al.* (2013) carried out an experiment to investigate the impact of farmyard manure and inorganic fertilizer application on soil physico-chemical properties. The results revealed that application of 15 t FYM ha^{-1} significantly increased soil organic matter and available water holding capacity but decreased the soil bulk density. They also found that application of 15 t FYM ha^{-1} increased the level of soil total nitrogen from 0.203 % to 0.349 % and the available phosphorous from 11.9 ppm to 38.1 ppm. Positive balances of soil N and P resulted from combined application of FYM and inorganic N and P sources. Application of 15 t ha^{-1} FYM and 120 kg N ha^{-1} resulted in 214.8 kg ha^{-1} N positive balance while application of 15 t ha^{-1} FYM and 100 kg P_2O_5 ha^{-1} resulted in a positive balance of 69.3 kg P_2O_5 ha^{-1} available P. They concluded that combined application of FYM and inorganic N and P fertilizers improved the chemical and physical properties of soil.

Uwah and Eyo (2014) conducted a field experiment at Calabar, in south eastern Nigeria to evaluate the effects of goat manure (GM) application, consisting of five doses of GM (0, 5, 10, 15 and 20 tonnes ha^{-1}) and NPK fertilizer (120:60:60 kg ha^{-1}) @ 400 kg ha^{-1} on soil chemical properties. The application of GM @ 20 tonnes ha^{-1} resulted in significant increase of soil pH, organic matter (OM) content, total N, available P, exchangeable K, Ca, Mg and the cation exchange capacity (CEC) status of the soil whereas soil exchangeable acidity (EA) was reduced from 1.76 to 0.64 cmol kg^{-1}.

Kapoor *et al.* (2015) conducted field trial at Hill Agricultural Research and Extension Centre Bajaura, Kullu, Himachal Pradesh to investigate the impacts of different management practices on physical and chemical properties of the soil comprising three treatments i.e., organic, inorganic and integrated management practice. In organic treatment, 50 % NPK was substituted by vermicompost and remaining by FYM, however, inorganic treatment applied was NPK- 20:40:60 kg ha^{-1} and integrated management comprised 50 % inorganic fertilizers and 50 % FYM. They observed that, the field capacity was maximum in integrated treatment (32.7 %) followed by organic treatment (30.1 %) and least in inorganic treatment (28.0 %), respectively. Application of organic treatment resulted in the highest organic carbon (1.8 g kg^{-1}) followed by integrated management and minimum (0.75 g kg^{-1}) under inorganic treatment. The available nitrogen content in the soil was found highest 485.5 kg ha^{-1} under the application of integrated management followed by organic treatment (440.4 kg ha^{-1}) and lowest (393.0 kg ha^{-1}) under inorganic treatment. Maximum amount of available phosphorous was observed in integrated management followed by organic treatment and the least amount was observed in inorganic treatment, however available potassium content of the soil was found to be highest (313.3 kg ha^{-1}) in integrated treatment and lowest (288.6 kg ha^{-1}) in the inorganic treatment.

Channal *et al.* (2016) carried out an experiment to study influence of organic and inorganic sources of nutrients on soil physico-chemical properties, where the results of the study revealed that water holding capacity, organic carbon, available N, P, K, S, Cu, Fe, and Mn in soil improved due to substitution of inorganic fertilizers with organic manures and the extent of improvement was higher at 100 per cent level. They found that the pH of soil in the treatment receiving only chemical fertilizers was 7.68 which decreased significantly due to substitution of RDN with organic manures namely FYM, vermicompost and poultry manure at 50 and 100 per cent levels. They recorded significantly higher water holding capacity of soil treated with 100 per cent RDN through organics (50 % FYM + 50 % VC) + recommend

FYM (63.7 %) and it was on par with other similar treatments with 100 % organics along with recommended FYM.

Han and Parker (2017) studied the effect of organic manure and chemical fertilizer on the growth and nutrient concentrations of yellow poplar. The seedlings (2 years old) were treated with organic manure (1000 g/m^2, mixture of poultry manure, cattle manure, swine manure and sawdust), NPK chemical fertilizer (urea, 30 g/m^2, fused superphosphate, 70 g/m^2, potassium chloride, 15 g/m^2), organic manure + NPK chemical fertilizer and control seedlings were left untreated. They found that chemical fertilizer decreased the soil pH and exchangeable calcium concentration, did not affect the soil concentrations of nitrogen and magnesium and increased the concentrations of available phosphorus and exchangeable potassium. In contrast, organic manure significantly increased the soil pH and the concentrations of nitrogen, available phosphorus, exchangeable potassium, calcium, and magnesium. They concluded that organic manure and sawdust can be utilized in seedling production systems for better growth and development.

Kyi and Aung (2017) evaluated the impact of organic manures and inorganic fertilizers on rice nutrients and soil characteristics consisting of three treatments *viz*., control (without fertilizer), organic farming (organic manures including paddy and black gram straw, cow dung) and conventional farming (chemical fertilizers including N, P, K). They recorded increase in physical and chemical properties (moisture, organic carbon, humus), nutrients (N, P, K) and decrease in Fe, Mg contents in the soil under organic farming when compared to conventional and control farming after paddy cultivation. Further, substantial increase in protein, fibre and decrease in fat were observed in the rice under organic farming. Thus, the results revealed that organic fertilizer resulted in better quality, safety and nutrition of rice as well as improved soil health.

Mahmood *et al.* (2017) conducted an experiment to investigate the effects of organic manures and inorganic fertilizers on maize and their residual impacts on physical and chemical properties of soil. Farmyard manure (FYM), sheep manure (SM) and poultry manure (PM) were applied as organic nutrient source while urea, diammonium phosphate (DAP) and sulphate of potash (SOP) were used at different concentrations as inorganic nutrients resulting substantial improvement in growth and yield of maize by fertilizer application alongside organic manures whereas soil total organic C, N, P and K contents increased when inorganic fertilizers were applied alone or in combined with organic manures. However, soil pH and bulk density decreased due to application of organic fertilizer and showed a negative correlation with grain yield. Thus, integration of inorganic fertilizers with organic manures can be used with optimum rates to improve crop productivity on sustainable basis.

Mehraj *et al.* (2017) studied the impact of organic manuring and inorganic fertilization on soil health and crop yield in soybean. The study showed that among the different combinations, application of 50 % N through FYM + inorganic sources of micro nutrients recorded significantly beneficial effect on crop yield of soybean onion cropping system. They recorded that the porosity, infiltration rate, soil pH, electrical conductivity, calcium carbonate and organic carbon improved with application of FYM + Vermicompost + Neem seed cake as compared to other treatments.

Mubarok *et al.* (2017) assessed the effect of organic manures and inorganic fertilizers application on improvement of soil chemical properties through combinations of different ratios (0/0; 0/1; 1/0; 0.5/0.5; 0.5/1; 1/0.5; 1/1.5; 1.5/0; 1.5/0.5, and 1.5/). They recorded that application of the combination of organic and inorganic fertilizers showed positive effects on soil pH, available-P, total-P, and fresh weight of tuberose. Results showed that application of 50 % organic fertilizer + 50 % inorganic fertilizer was an effective combination that was able to increase the fresh weight of tuberose up to 9240 g plant^{-1} or increasing the fresh weight by 39 % in comparison to that in the control treatment (without fertilizer application).

Tripathi *et al.* (2017) studied the soil parameters under peach-based agroforestry system and monocropping with the application of three different treatment doses of FYM (15, 20 and 25 t ha $^{-1}$) and vermicompost (2, 4 and 6 t ha^{-1}). They reported highest soil pH (7.41), soil organic carbon content (2.16 % at 0-15 cm and 1.75 % at 15-30 cm) and lowest soil bulk density (1.02 mg m^{-3}) under peach where, FYM @ 25 t ha^{-1} was applied as compared to other doses of organic manures however, soil electrical conductivity was recorded maximum (0.28 d S m^{-1}) in vermicompost @ 6 t ha^{-1} under peach-based agroforestry.

Yadav *et al.* (2017) conducted an experiment to assess the effect of integrated nutrient management on soil properties and yield of wheat. The experiment was laid out in randomized block design consisting of 8 treatments *viz*., T_1 (control), T_2 (100 % RDF), T_3 (75 % RDF), T_4 (75 % RDF + 25 % N-FYM), T_5 (75 % RDF + *Azotobacter*), T_6 (50 % RDF + 50 % N-FYM) T_7 (50 % RDF + 50 % N-FYM + PSB) and T_8 (50 % RDF + *Azotobacter* + PSB). The results of the experiment showed that highest yield and yield attributes were recorded in treatment T_7 being significantly superior over control as well as T_3, T_5 and T_8 treatments.

They also found that maximum, soil organic carbon (4.4 g kg^{-1}), available nitrogen (195.2 kg ha^{-1}), phosphorus (12.4 kg ha^{-1}) and potassium (215.5 kg ha^{-1}) was recorded under treatment T_7 and minimum under control.

Devi *et al.* (2018) studied the effect of integrated nutrient management on soil physico-chemical properties and yield of Capsicum. The experiment consisted of 9 treatments *viz*., T_1 - Absolute control, T_2 - 70 % NPKM + 30 % N through FYM and VC (50:50), T_3 - 80 % NPKM + 20 % N through FYM and VC (50:50), T_4 - 90 % NPKM + 10 % N through FYM and VC (50:50), T_5 - 100 % NPK + FYM, T_6 - 100 % NPK + Vermicompost, T_7 - 110 % NPKM (50:50 of FYM and VC as per N content), T_8 - 120 % NPKM (50:50 of FYM and VC as per N content), T_9 - 130 % NPKM (50:50 of FYM and VC as per N content). They reported that organic carbon content was significantly higher under treatment T_9 (12.84 g kg^{-1}) which was statistically at par with T_8 (12.75 g kg^{-1}) and T_3 (12.58 g kg^{-1}) and lowest (10.31 g kg^{-1}) under T_1. Similar trend was recorded in available NPK content in soil, T_9 having highest content and T_1 lowest.

Li *et al.* (2018) assessed the influence of long-term fertilization on soil physicochemical properties in a brown soil. The experiment comprised of six treatments *viz.,* no fertilizer (CK), N_1 (mineral nitrogen fertilizer), N_1P (mineral nitrogen and phosphate fertilizer), N_1PK (mineral nitrogen, phosphate and potassic fertilizer), pig manure (M_2), M_2N_1P (pig manure, mineral nitrogen and phosphate fertilizer). The results showed that the long-term application of chemical fertilizers reduced soil pH value, while the application of organic fertilizers increased pH value. They also found that fertilization significantly increased the content of alkali-hydrolysable nitrogen, total nitrogen and soil organic matter. However, compared with the no fertilizer treatment and chemical fertilizer treatments, organic fertilizer treatments significantly increased the content of available phosphorus and total soil phosphorus. Whereas there was no significant difference among different treatment the content of available potassium and total soil phosphorus.

Lalito *et al.* (2018) conducted an experiment compromising of eight treatment combinations *viz.,* T_1 : control, T_2 : NPK 100 per cent, T_3 : FYM @ 10 tonnes ha^{-1}, T_4 : Vermicompost @ 10 tonnes ha^{-1}, T_5 : NPK 100 per cent + FYM @ 10 tonnes ha^{-1}, T_6 : NPK 100 per cent + Vermicompost @ 10 tonnes ha^{-1}, T_7 : NPK 100 per cent + FYM @ 10 tonnes ha^{-1} + Vermicompost @ 10 tonnes ha^{-1} and T_8 : FYM @ 10 tonnes ha^{-1} + Vermicompost @10 tonnes ha^{-1}. Among all the treatments, treatment T_7 recorded higher value of soil available N,

P_2O_5 and K_2O after crop harvesting, which is closely followed by T_5 (NPK + FYM), whereas it was recorded lowest in T_1 (control).

Nemera *et al.* (2018) evaluated the soil physical and chemical properties of the degraded natural grassland through application of chemical fertilizer, cattle manure, wood ash and lime in randomized complete block design. The lab analysis of soil before the experiment indicated that the soil was salt free, slightly acidic pH, higher in cation exchange capacity, low in available P, the organic carbon and total nitrogen were rich, higher in exchangeable Ca. Mg, Na and K valuing 3.6, 0.46 and 12, respectively. Further, the results of the study revealed that application of wood ash increased the soil pH while application of cattle manure and wood ash increased available phosphorous and exchangeable potassium respectively.

Ayer *et al.* (2019) in their experiment on effect of soil conditioner on carrot growth and soil fertility status showed that maximum organic matter (3.09 %), available phosphorus (177.26 kg/ha) and potassium (116.81 kg/ha) were recorded by application of 120 kg/ha GMT ™ soil conditioner + 60 kg/ha agro gold micronutrient + 50 % RDF + 50 % FYM. Maximum available nitrogen (0.01 %) and pH (6.1) were recorded by application of 60 kg/ha GMT ™ soil conditioner + 30 kg/ha agro gold micronutrient + 50 % RDF + 50 % FYM.

Aziz *et al.* (2019) conducted a study to assess the effect of integrated nutrient management on Soybean under temperate conditions in factorial randomized block design with 3 levels of inorganic fertilizer (50, 75 and 100 % Recommended Dose), 3 levels of organic manures (control, FYM 10 t ha^{-1} and Dalweed 10 t ha^{-1}) and 2 levels of biofertilizers (control and dual inoculation with Rhizobium + PSB i.e., phosphate solubilising bacterial strain), replicated three times. The results of the experiment revealed that application of recommended inorganic fertilizers enhanced soil physical properties except for bulk density. They further concluded that among organic manures, FYM (10 t ha^{-1}) was found superior over rest of the treatments.

Jagadeesha *et al*. (2019) studied the effect of organic manures on physical, chemical and biological properties of soil and crop yield in finger millet-red gram intercropping system. Different organic manures @ 50 kg N equivalent used in the experiment are farm yard manure, urban garbage compost, enriched urban garbage compost, sewage sludge, poultry manure compost and vermicompost compared to inorganic fertilizers alone. They found that organic sources of nutrients tended to improve soil physical and chemical properties *viz*., bulk density, water holding capacity, porosity and organic carbon. The highest organic carbon content (0.68 %) was recorded with the application of sewage sludge followed by poultry manure. Result also revealed that highest soil microbial population *viz.,* bacteria, fungi, actinomycetes population, microbial biomass carbon and microbial biomass N (23.54 x 107 cfu/g, 25.65 x 104 cfu/g and 23.04 x 103 cfu/g, 2131.8 mg/g and 239.7 mg/g of soil, respectively) were recorded in application of sewage sludge @ 50 kg N equivalent followed by poultry manure compost and lowest in inorganic fertilizer.

Sankaramoorthy and Rangasamy (2019) studied effect of different sources of organic manures on soil physical and chemical properties, consisting the field experiment deliberated in randomized block design, replicated thrice, where twelve organic treatments were compared with recommended doses of fertilizers (RDF) and integrated nutrient management (INM). The results revealed that less bulk density, more per cent pore space and water holding capacity were recorded in all organic treatments and the INM whereas the higher bulk density, lesser per cent pore space and water holding capacity was recorded with RDF. They also found that soil available NPK and uptake of NPK at harvest of rice, was recorded higher with INM followed by RDF, whereas among the organic treatments, 100 % RDN through green manure followed, by 25 % RDN through each organic manures recorded more soil available and uptake of major nutrients.

Kharadi and Bhuriya (2020) studied the impact of organic manures and inorganic fertilizers on soil chemical properties, where organic manure treatments consisted of M_1: Control, M_2: FYM @ 4 t ha^{-1}, M_3: Vermicompost @ 1 t ha^{-1} and the inorganic fertilizers treatments were F_1: Control, F_2: 50 % RDF, F_3: 75 % RDF, F_4: 100 %. The results showed that organic carbon, available N_2O and available P_2O_5 of soil analysed at harvest were significantly higher with the application of 100 % RDF (20 kg N + 40 kg P_2O_5 ha^{-1}) which was at par with 75 % RDF (15 kg N + 30 kg P_2O_5 ha^{-1}). They concluded that interactive effect of organic manures and inorganic fertilizers on physico-chemical properties of soil were found to be non-significant at harvest.

Noor *et al.* (2020) evaluated the impact of compost and chemical fertilizer application on soil physical properties and productivity of sesame, consisting seven different farming treatments including sole compost levels (20 and 30 t ha^{-1}), sole chemical fertilizer (NPK, 30 kg ha^{-1}), integrated fertilizer treatments (compost + RDF) and a control. The results showed that a significantly higher grain yield of sesame (805.1 kg ha^{-1}) was obtained from integrated fertilizer application (30 t ha^{-1} compost + ½ RDF). Integrated farming treatments have significantly improved the soil field capacity, available moisture to plants and wilting point when compared with sole RDF and compost. They concluded that the integrated farming system is best option for sustainable crop production.

Sharma *et al.* (2020) carried out an experiment to assess the effect of organic manures on soil physical and chemical properties of *Ocimum sanctum* under peach and apricot based agroforestry system having seven different treatments with three levels laid out in factorial randomized block design. They reported that among different organic manure treatments, FYM (25 t/ha) significantly influenced the physical as well as chemical properties of soil. The results revealed that highest soil moisture (11.20 % and 11.27 %), electrical conductivity (0.29 and 0.29), organic carbon (2.35 % and 2.12 %), available nitrogen (354.97 and 255.42), available phosphorus (55.08 and 53.88) and available potassium (356.40 and 278.96) was recorded under FYM (25 t/ha) treatment and lowest under control when applied at a distance of 1m away from tree trunk.

Devkota *et al.* (2021) assessed the effects of different doses of organic and inorganic fertilizers on soil properties. The experiment, laid out in a randomized complete block design consisting of ten treatments with different combinations of organic and inorganic fertilizers revealed that highest nitrogen (0.10 %), organic matter (1.89 %) and phosphorus content (169.09 mg/kg) were obtained with the application of combined half dose of NPK (105:90:60 kg NPK/ha) and half FYM @ 20 t FYM/ha. They, further concluded that combined effect of application of organic manures with inorganic fertilizers (NPK) was better for crop growth and development as well as soil health improvement.

Ejigu *et al*. (2021) conducted an experiment to assess the impact of integrated fertilizer application on soil properties and maize yield consisting of factorial combinations of three rates of Urea/NPSB (0/0, 50/50 and 100/100 kg ha^{-1}) and three rates of compost (0, 5 and 10 t ha^{-1}). Results revealed that combined application of compost and mineral fertilizer significantly increased soil pH, organic carbon, total nitrogen, available phosphorus, available sulphur and cation exchange capacity compared to sole mineral fertilizer application and the control. Plots treated with 10 t ha^{-1} compost and 100/100 kg ha^{-1} Urea/NPSB provided the highest maize dry biomass (18.62 t ha^{-1}) and grain yield (6.07 t ha^{-1}). Whereas the lowest, biomass (5.70 t ha^{-1}) and grain (1.17 t ha^{-1}) yields were obtained from the control.

Okhumata *et al*. (2021) evaluated the effects of integrated application of inorganic and organic fertilizer on properties of soil in rice field, where the results showed that combine application of organic and inorganic fertilizer significantly improved soil nutrient status compared to the other treatments. Further they found that the combined application of inorganic and organic fertilizer increased soil pH value from 5.64 to 6.92. They concluded that there was a significant improvement of the macro and micronutrient from the integrated application of inorganic and organic based fertilizers compared to other treatments. Thus, the integrated applications of organic and inorganic fertilizer significantly improve the chemical and physical properties of soil.

Azuka and Idu (2022) studied the impact of application of organic manures on soil physical and chemical properties and Okra productivity in greenhouse experiment in a completely randomized design, while the field experiment was laid out in a randomized complete block design. The study comprised of eight treatments *viz.,* poultry manure (PM) and pig slurry (PS) at 10, 20 and 40 t ha^{-1} respectively, NPK 15:15:15 at 300 kg/ha and control with no amendment. Further the results revealed that PM and PS significantly improved soil pH, soil organic matter, available phosphorous, total nitrogen, aggregate stability, mean weight diameter, bulk density, porosity and saturated hydraulic conductivity in greenhouse and field studies. Similarly, PM and PS significantly improved agronomic parameters than the control, however they found that poultry manure showed its superiority over other amendments in improving soil and agronomic properties. They recommended 20 t ha^{-1} of PM and 40 t ha^{-1} of PS for sustainable soil and optimum productivity of okra.

Wagari *et al*. (2022) studied the effect of vermicompost and blended NPS fertilizers on soil physical and chemical properties where the treatment included four rates of blended NPS fertilizers (0, 150, 200 and 250 kg NPS ha^{-1}) and four of vermicompost (0, 4, 6 and 8 t ha^{-1}) in factorial combination in randomized complete block design with 3 replications. Results showed that the incorporation of vermicompost and NPS fertilizer increased OC, CEC, available P and K and total N content of the soil. They recorded organic carbon, available P and available K were increased by 8.7, 14.9 and 13.0 % over the initial status, respectively. Combined application of 250 kg ha^{-1} blended NPS fertilizer and 8 t ha^{-1} vermicompost gave significantly maximum yield for marketable tuber yield (27.4 t ha^{-1}) and total tuber yield (27.9 t ha^{-1}). Thus, the integrated use of various rates of vermicompost (VC) and low rates of inorganic fertilizer is better than independent use of inorganic fertilizer.

2.3 BIO-ECONOMIC APPRAISAL OF WILD POMEGRANATE-BASED AGROFORESTRY

Gopinath *et al*. (2011) studied the effect of various organic sources (farmyard manure, poultry manure and vermicompost) and biofertilizers [*Rhizobium leguminosarum* + phosphorus-solubilizing bacteria (*Pseudomonas* sp.)] on yield and economics of garden pea, where highest pod yields (7.02 and 7.52 tonnes/ha) was recorded with application of farmyard manure @ 10 tonnes/ha + poultry manure and vermicompost each 1.5 tonnes/ha + biofertilizers and it was significantly superior to other treatments. The study revealed that application of FYM @ 10 tonnes/ha + recommended NPK gave highest net return of Rs 63, 529 compared to other treatments.

Singh (2011) assessed the effect of organic farming on productivity, soil fertility and economics of rice, tomato and bottle gourd cropping system. The study comprised of seven treatments namely*, Azotobacter* + FYM, FYM, Goat manure, Vermicompost, *Azolla* + FYM, cow urine and control. The results revealed that *Azolla* + FYM recorded the highest rice grain yield of 2.68 t ha^{-1} which was at par with vermicompost (2.55 t ha^{-1}), *Azotobacter* + FYM (2.41 t ha^{-1}) and FYM (2.37 t ha^{-1}). However, vermicompost recorded significantly highest yield of tomato as well as bottle gourd which was at par with *Azotobacter* + FYM and FYM treatment. They also recorded that higher net return of Rs 3, 11, 958 ha^{-1} with benefit: cost ratio 3.59 was obtained with the application of vermicompost which was followed by net return of Rs 2, 98, 628 and B: C ratio of 3.42 with the addition of *Azotobacter* + FYM and net return of Rs 2, 77298 and B: C ratio of 3.25 by FYM treatment.

Sujatha *et al.* (2011) studied the feasibility of intercropping of medicinal and aromatic plants (MAPs) in arecanut plantation at Vittal, Karnataka, India during the years 2004–2007. The results revealed that MAPs can be successfully grown as intercrops in arecanut plantation with increased productivity and net income per unit area. Kernel equivalent yield of MAPs varied between 272 kg ha^{-1} in case of *Piper longum* to 1218 kg ha^{-1} in *Cymbopogon flexuosus*. The benefit cost ratio was highest in *C. flexuosus* (4.25) followed by *Bacopa monnieri* (3.64), *Ocimum basilicum* (3.46) and *Artemisia pallens* (3.12). The total system productivity of arecanut + MAPs intercropping system varied from 2990 to 4144 kg ha^{-1}. Arecanut + *O. basilicum* intercropping system registered significantly higher production efficiency 8.2 kg ha^{-1} day $^{-1}$ than other systems, however, intercropping of MAPs in arecanut was found economical.

Davari *et al*. (2012) conducted an experiment to study the effect of organic manures and biofertilizers on productivity and economics of wheat. Where, the experiment comprised of a control (no fertiliser) and six fertiliser treatments *viz*., farmyard manure (FYM), vermicompost (VC), FYM + rice residue (RR), VC + RR, FYM + RR + biofertilizers (B), and VC + RR + B. FYM and VC were applied on nitrogen equivalent basis (60 kg ha^{-1}), whereas RR was applied at the rate of 6 t ha^{-1}. The study revealed that VC + RR + B was the most productive treatment, while FYM + RR + B was the most economical treatment with respect to increasing net profit because of the higher price of vermicompost than FYM. It was also observed that both of these combinations resulted in improved grain quality and nutrient uptake by grain. Thus, they concluded that the combination of FYM + RR + biofertilizers or VC + RR + biofertilizers hold promise for organic wheat farming.

Sarma *et al.* (2015) studied the effect of organic manure, vermicompost and neemcake on growth, yield and profitability of turmeric (*Curcuma longa*) variety - Megha. Where, treatment groups consisted of T_1: Absolute control T_2: Vermicompost + Neemcake + *Trichoderma harzianum*, T_3: FYM + Neemcake + *Trichoderma harzianum* T_4: FYM + Vermicompost + Neemcake + *Trichoderma harzianum*. The results revealed that the combined applications of FYM + Vermicompost + Neemcake i.e., T_4 resulted in maximum plant height (75.02 cm), girth of rhizome (15.76 cm), weight of rhizome (500.00 g) and rhizome yield (20.48 tonnes ha^{-1}); whereas, the minimum plant height (52.50 cm), girth of rhizome (10.25 cm), weight of rhizome (450.22 g) and rhizome yield (12.50 tonnes ha^{-1}) were observed in the absolute control. Further highest rhizome yield (20.48 tonnes ha^{-1}) with maximum benefit-cost ratio (3.6:1) was obtained in the treatment combination T_4 and the lowest yield (12.50 tonnes ha^{-1}) was obtained in the treatment T_1 with minimum benefit-cost ratio (3.1:1).

Kamble *et al*. (2016) evaluated the effect of organic and inorganic fertilizers on growth, yield and economics of French bean. They reported that organic manures and inorganic fertilizers combinations significantly increase the growth and green pod yield of French bean. Maximum number of branches, number of leaves, mean leaf area, length of pod, diameter of pod, number of pods, plant height, weight of pod, green pod yield (30.98 q per ha^{-1}) was recorded in 100 % NPK + PM @ 5 t ha^{-1} which was significantly higher than other treatments. Highest net returns (Rs 48, 013 ha^{-1}) and BCR (2.33) was obtained with application of 100 % NPK+ PM @ 2.5 t ha^{-1} followed by 100 % NPK + VC @ 2.5 t ha^{-1} with BCR (2.11).

Manohar and Paliwal (2016) reported that the combined use of FYM @ 15 t ha^{-1} and 75 % RDF + B + Zn proved to be the best treatment combination in terms of primary branches per plant, average number of fruits per plant, fruit yield, net returns and B:C ratio of tomato. This combination produced 372.77 q ha $^{-1}$ fruit yield along with net returns of Rs 178452 ha^{-1} and B:C ratio of 3.94.

Kumar *et al.* (2016) conducted an experiment to study the effect of shade and organic manure on growth and yield of Patchouli under Teak based agroforestry system. The experiment was laid out under two planting conditions i.e., teak based agroforestry system and under open condition with seven treatments designated as T_0 (Control), T_1 (100 % FYM (20 t ha^{-1}), T_2 100 % vermicompost (10 t ha^{-1}), T_3 100 % Neem cake (0.5 - 1.0 t ha^{-1}), T_4 50 % FYM + 50 % Neem cake, T_5 50 % vermicompost + 50 % Neem cake, T_6 50 % FYM + 50 % vermicompost. The results showed that dry herbage and oil yield of Patchouli were highest under shade condition with treatment T_2 (100 % vermicompost) compared to open condition at three harvest intervals. The chemical composition of the essential oils was also evaluated quantitatively and qualitatively. The major compounds (Patchouli alcohol) were also higher (42.3, 42.9 % in the year 2009-10 and 2010-11 respectively) under agroforestry system compared with open condition. The highest net return was recorded in T_2 (Rs 53, 013) followed by T_6 (Rs 52, 396) and the BC Ratio was recorded as 1:2.35 in T_6 followed by T_2 (1:2.32) under agroforestry. Furthermore, it was concluded that *Pogostemon cablin* is a shade tolerant plant and its growth, yield and quality favoured under teak tree shade, thus can be explored as intercrop under agroforestry.

Shivran *et al.* (2016) conducted an experiment to assess the effect of integrated nutrient management on productivity and economics of fenugreek. The experiment was deliberated in randomized block design consisting fourteen combinations of different inorganic or organic sources [farmyard manure (FYM), poultry manure (PM), vermicompost (VC) and neem cake (NC)] alone or in combinations and control. They found that the integration of 50 % RDN through vermicompost (VC) + 50 % RDN through inorganic source to fenugreek gave higher plant height, branches per plant, pods per plant, seeds per pod, test weight, seed yield (1781 kg/ha), stover yield (3392 kg/ha), biological yield (5173 kg/ha) and net returns (Rs 52151/ha). However, maximum benefit cost ratio was recorded with application of 100 % RDN through inorganic source.

Thakur *et al.* (2016) studied the economics of cultivation three *Ocimum* species, namely *O. tenuiflorum*, *O. gratissimum* and *O. basilicum*, which were grown under 18-year-old teak (*Tectona grandis*) based silvi-medicinal (teak + *Ocimum* spp.) and sole cropping systems through value addition due to herb and oil production. The results revealed that herbage production of *O. gratissimum* provided highest net returns of Rs 38,018 ha^{-1} (benefit-cost ratio (BCR): 1.85) when grown under sole cropping and Rs 25,418 ha^{-1} (BCR: 1.24) when grown under silvi-medicinal system. The essential oil production from *O. basilicum* accrued the highest net returns of Rs 103327 ha^{-1} with BCR of 2.56. The analysis of NPV, IRR, PBP and BCR suggested that cultivation, either sole crop or under silvi-medicinal system of *O. gratissium* for raw herbage and of *O. basilicum* for essential oil production is profitable.

Choudhary *et al.* (2017) conducted a study to evaluate the effect of organic manures and mineral nutrients on quality parameters and economics of sesame. The experiment consisted of sixteen treatments combination comprising four levels of organic manures (control, FYM @ 10 t ha^{-1}, Vermicompost @ 5 t ha^{-1} and FYM @ 5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1}) and four levels of mineral nutrients (control, S @ 20 kg ha^{-1}, S @ 20 kg ha^{-1} + Fe @ 10 kg ha^{-1} and S @ 20 kg ha^{-1} + Fe @ 10 kg ha^{-1} + Zn @ 5 kg ha^{-1}) deliberated in randomized block design. They recorded that the application of FYM @ 5 t ha^{-1} + vermicompost @ 2.5 t ha^{-1} and mineral nutrients S @ 20 kg + Fe @ 10 kg + Zn @ 5 kg ha^{-1} significantly increased protein content, oil content and oil yield and net returns (Rs 45,531 M_3) and (Rs 47,646 T_3) over rest of the treatments.

Kumar *et al*. (2017) evaluated the impact of integrated nutrient management on growth, yield and quality parameters of tomato. They reported that application of 43.5 tonnes farm yard manure (FYM) and 50 % recommended dose of fertilizers (RDF) gave maximum yield (284.81 q ha^{-1}) over control (198.6 q ha^{-1}) which was significantly higher over all the treatments except green manuring and 100 % recommended dose of fertilizer. Maximum net return (Rs 40203 ha^{-1}) and B:C ratio (1.29) was also recorded with application of 43.5 tonnes FYM and 50 % RDF over control. Thus, they concluded that organic sources of nutrition along with inorganic showed incremental effect for almost all parameters including yield over inorganic sources alone.

Ramesh (2017) studied the effect of organic manures and inorganic fertilizers on productivity and economics of rice – cotton cropping system, where the results showed that combined application of 100 % RDN + vermicompost @ 5 t ha^{-1} to rice and 75 % RDF to cotton under rice - cotton cropping system is economically viable, an eco-friendly and biologically active system that can be recommended to the farmers. Although in case of nonavailability of vermicompost, green manuring @ 6.25 t ha^{-1} + 100 % RDN to rice and 100 % RDF to cotton under rice - cotton cropping system, may be a good alternative to augment rice and cotton yields, besides helping in the maintenance of soil health. He also found that maximum gross return (Rs 81360.92 and 86546.75 during phase I and phase II, respectively) was recorded in T_5S_3 (100 % RDN + vermicompost @ 5 t ha^{-1} imposed to rice followed by 100 % RDF to cotton).

Mahata *et al.* (2018) evaluated the effect of organic manures on Buckwheat – fodder Rice bean cropping system in a randomized block design with fourteen treatments comprising of farmyard manure, vermicompost, mustard cake, poultry manures, and their combinations replicated thrice. The study revealed that maximum gross return of Rs 91,500 and Rs 97,920 ha^{-1} were achieved with collective application of vermicompost @ 2.5 t ha^{-1} + mustard cake @ 2.5 t ha^{-1} + poultry manure @ 2.5 t ha^{-1} + F.Y.M @ 4 t ha^{-1}, whereas the highest benefit cost ratio (2.33 and 2.59 during first and second year, respectively) was recorded in 100 % RDF application.

Solanki (2018) conducted a field experiment during kharif season 2011 and 2012 at Agronomy farm, Navsari Agricultural University, Navsari, Gujarat. Three medicinal plants *viz.,* Basil (*Ocimum sanctum* L.), Kalmegh (*Andrographis paniculata* Well.) and Mint (*Mentha arvensis* L) were selected for the study. The experiment was carried out in randomized block design with six treatments T_1 – *Manilkara achras* + *Jatropha curcas* + *Ocimum sanctum*, T_2 – *Manilkara achras* + *Jatropha curcas* + *Andrographis paniculata*, T_3 – *Manilkara achras* + *Jatropha curcas* + *Mentha arvensis*, T_4 – *Ocimum sanctum* sole, T_5 – *Andrographis paniculata* sole, T_6 – *Mentha arvensis* sole with four replications. The maximum BCR was recorded under treatment T_1 (3.10) followed by treatment T_2 (2.87) whereas, minimum under treatment T_6 (1.65) followed by T_5 (2.05). Meanwhile, the maximum land equivalent ratio (LER) was recorded treatment in T_1 and T_3 (1.27) followed by T_2 (1.20).

Vijaykumar *et al.* (2018) studied the effect of organic manure on growth and economics of rice cultivation under citrus based agroforestry system. The experiment comprising nine treatment combinations consisting of three levels of organic manure [FYM 10 t/ha, poultry manure (PM) 2 t/ha, vermicompost (VC) 5 t/ha] revealed that the highest gross return (Rs ha^{-1}) 87,092, cost of cultivation (Rs ha^{-1}) 56,390, net return (Rs ha^{-1}) 30,701 and benefit cost ratio (B.C. ratio) 1:5.4 was recorded in treatment T_5 (75 % RDN through FYM + 25 % RDN through PM), which was significantly higher than other treatment.

Altaf *et al*. (2019) studied the effect of NPK, organic manure and their combination on growth, yield and nutrient uptake of chilli. The experiment consisted of nine treatment combinations *viz.,* T_1: control (without NPK, GC, C, PM, VC and FYM), T_2: N 100 %, T_3: P 100 %, T_4: K 100 %, T_5: NPK 100 % + GC, T_6: NPK 100 % + C, T_7: NPK 100 % + PM, T_8: NPK 100 % + VC and T_9: NPK 100 % + FYM. The results revealed that plant height at harvesting, number of fruits plant^{-1}, number of branches plant^{-1}, fruit weight, fruit width and fruit length was recorded highest in treatment T_9 (N: P: K 100:50:50 + FYM @ 8 ton per hectare). They also reported that application of NPK 100 % + FYM @ 8 ton per hectare increased ascorbic acid content and oleoresin yield. They further concluded that the highest net return (Rs 30183 per hectare) was achieved with the application of NPK 100 % + FYM @ 8 ton per hectare followed by NPK 100 % + PM @ 6 ton per hectare, NPK 100 % + VC @ 10 ton per hectare and NPK 100 % + C @ 7 ton per hectare.

Gowthamchand *et al*. (2019) conducted an experiment to study the effect of bulky manures and fermented liquid organics on growth, yield and economics of French bean, where the experiment comprised of ten treatments of different bulky organic manures (FYM and vemicompost and fermented liquid organic manures (Beejamrutha, jeevamrutha, panchagavya and cow urine) and their combination laid out in randomized block design. The results revealed that highest gross return (Rs 24, 6450) and net return (Rs 19,8794) were recorded with application of Beejamrutha (seed treatment) + Jeevamrutha (soil application @ 500 l ha^{-1}) + 100 % RDN through vermicompost + Foliar spray of Panchagavya @ 3 %. Author came to the conclusion that applying organic manures along with fermented liquid organics had a higher benefit to cost ratio than a treatment that used either liquid organics or solely organic manures.

Parewa *et al.* (2019) studied the impact of organic nutrient management practices on yield and economics of Wheat. The experiment was laid out in randomized block design with seven treatments resulting in maximum plant height (85.83 cm), number of seed per head (55.18) and grain yield (39.14 q ha^{-1}) recorded under the FYM @ 10 t ha^{-1} + vermicompost @ 1.25 t ha $^{-1}$ followed by the treatment FYM @ 5 t ha^{-1} + neem green leaves @ 2 t ha^{-1} + vermicompost 1.25 t ha^{-1}. Similarly, the net return was significantly high with FYM @ 10 t h^{-1} + vermicompost @ 1.25 t ha^{-1} whereas B:C ratio (2.43) was highest with FYM t ha^{-1} + neem green leaves @ 2 t ha + Vermicompost @ 1.25 t ha.

Singh *et al.* (2020) evaluated the influence of organic manures on nutrient uptake and economics of mustard crop. The experiment comprised of six treatments *viz*., one 100 %

fertilizer, one integrated (FYM + Fertilizer) and four 100 % organic consisting various combinations of organic sources (FYM, Vermicompost, Neemcake, PSB, Azotobacter), tested in randomized block design. The study reported on the basis of economics of different treatment, the higher gross returns (Rs 78598 ha^{-1}), net returns (Rs 59067 ha^{-1}) and benefit cost ratio (3.02) was recorded under integrated treatment (FYM + fertilizer) for mustard crop.

Massey *et al.* (2021) conducted an experiment to evaluate the effects of organic manures i.e., M_1-Vermicompost (2.5 t/ha), M_2-FYM (5.0 t/ha), M_3-Vermicompost (2.5 t/ha) + *Azotobacter* and M_4-FYM (5.0 t/ha) + vermicompost (2.5 t/ha), and green manuring *viz*., G_1-clusterbean, G_2-cowpea, G_3-sun hemp and G_4-dhaincha on economics of lemongrass under custard apple based agri-horti system. The experiment was laid out in a split plot design where organic manures treatments were allotted to main plot and green manuring treatments to the sub plot. They reported that application of vermicompost (2.5 tonnes/ha) + *Azotobacter* (M_3) resulted in highest gross return (Rs 7, 01,059), net return (Rs 5, 56,356) and B:C ratio (4.68). Among green manuring treatments, manuring with dhaincha gave significantly high gross return (Rs 5, 51,498), net return (Rs 3, 93,730) and B:C ratio (3.52) whereas the lowest return were recorded in FYM (M_2).

Priyadharshini *et al.* (2021) studied the impact of spacing and organic manures on growth, yield and economics of Mung Bean. The experiment consisted of various combination of spacing and organic manures *viz*., 30×10 cm^2, 40×10 cm^2, 50×10 cm^2 and application of Vermicompost @ 4 t/ha, FYM @ 10 t/ha and Poultry manure @ 2 t/ha. The results revealed that spacing (30×10 cm^2) and organic manures (FYM 10 t/ha) treatment recorded significantly higher number of pods/plant (40.27), test weight (27.33g), seed/pod (9.13), seed yield (1046.67 kg/ha), stover yield (2583.67 kg/ha), biological yield (3630.00 kg/ha) and harvest index (28.85 %). Similarly highest gross returns (Rs 64091.83 per ha), net returns (Rs 35921.83 per ha) and B:C ratio (2.26) was recorded with combination of spacing and organic manures 30 ×10 cm^2 + FYM 10 t/ha.

Tyagi *et al.* (2022) conducted an experiment to assess the impact of organic manures and biofertilizers on growth, yield and economics of cauliflower. The treatments comprised of different doses of organic manures (FYM, poultry manure and vermicompost), the bio-fertilizer (VAM and *Azotobacter*) and combination of the two. The study reported that application of 50 % vermicompost resulted in maximum growth attributes (green leaves per plant 8.2, length of longest leaf 33.9 cm, width of longest leaf 21.3 cm, plant height 33.1 cm, spread of plant across row length 34.2 cm and spread of plant along row 35.0 cm). Similarly highest curd yield of cauliflower (36.6 q ha^{-1}), net return of Rs 157950 ha^{-1} and B:C ratio (4.031) were recorded with 50 % vermicompost. They further reported that application of 80% poultry manure proved next best treatment with respect to yield and economics of cauliflower. The lowest values of all parameters were recorded under control.

Yadav *et al.* (2022) assessed the effect of different organic manures on growth, yield, and economics of kharif season maize. The study trial comprised of nine treatments in randomized block design with three replications *viz.*, T_1: FYM @ 5 t ha^{-1}, T_2: FYM @ 10 t ha^{-1}, T_3: FYM @ 15 t ha^{-1}, T_4: VC @ 5 t ha^{-1}, T_5: VC @ 10 t ha^{-1}, T_6: VC @ 15 t ha^{-1}, T_7: BK (Bokashi Manure) @ 5 t ha^{-1}, T_8: BK @ 10 t ha^{-1}, T_9: BK @ 15 t ha^{-1}. The results revealed that application of vermicompost @ 15 tonnes ha^{-1} significantly enhanced productivity parameter i.e., green fodder yield (9810.67 kg ha^{-1}), grain yield (3544.33 kg ha^{-1}), biological yield (13355 kg ha^{-1}) and harvest index (26.54 %) followed by Bokashi Manures @ 15 tonnes ha^{-1}. The study further showed that highest values of economics *viz.*, gross return (Rs 167915.9 ha^{-1}), net return (Rs 333875.9 ha^{-1}) and B:C ratio in maize was observed with the application of vermicompost @ 15 tonnes ha^{-1}.

Chapter-3

MATERIALS AND METHODS

The study entitled **"Effects of organic manures on growth, yield and oil quality parameters of lemon grass under wild pomegranate based agroforestry system"** was conducted in the experimental farm at Pandah village farm, Department of Silviculture and Agroforestry, College of Forestry, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. The detailed account of study area and methodology adopted is as follow:

3.1 EXPERIMENTAL SITE

3.1.1 Location

The experimental site is located in the mid-hill zone of Himachal Pradesh at 30^0 51' 06'' N Latitude and 77^0 09' 49'' E Longitude, with an elevation of 1200 m above mean sea level. It is situated 15 km south-east of Solan town and represents transitional zone between subtropical and sub temperate region of state of Himachal Pradesh (Figure 1).

3.1.2 Climate

The experimental area falls in sub-tropical belt and sub-humid agro-climatic zone of Himachal Pradesh, India. There is considerable variation in the seasonal and diurnal temperature. In general, May and June are the hottest months and December and January are the coldest ones. The average annual temperature is 17.4 °C. The annual rainfall varies from 1000-1400 mm; about 75 per cent of it is received during monsoon period (mid-June- mid September). The area experiences severe frost in winters, however the snowfall is of rare occurrence. The meteorological data for the period of research work was procured from the Department of Environmental Science of Dr. Y S Parmar University of Horticulture and Forestry, Nauni, Solan (Figure 2).

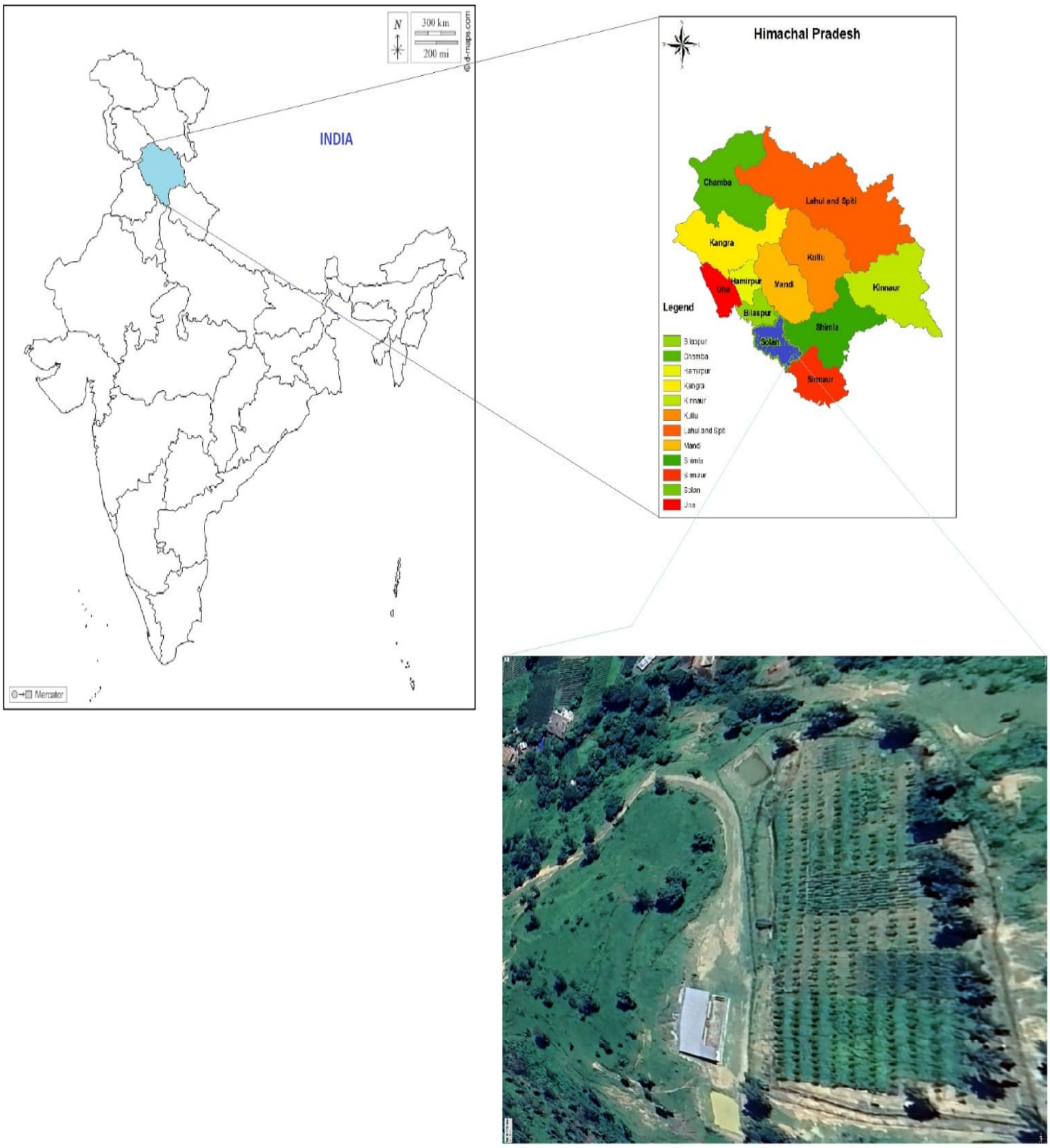


Figure 1: Location of the experimental farm

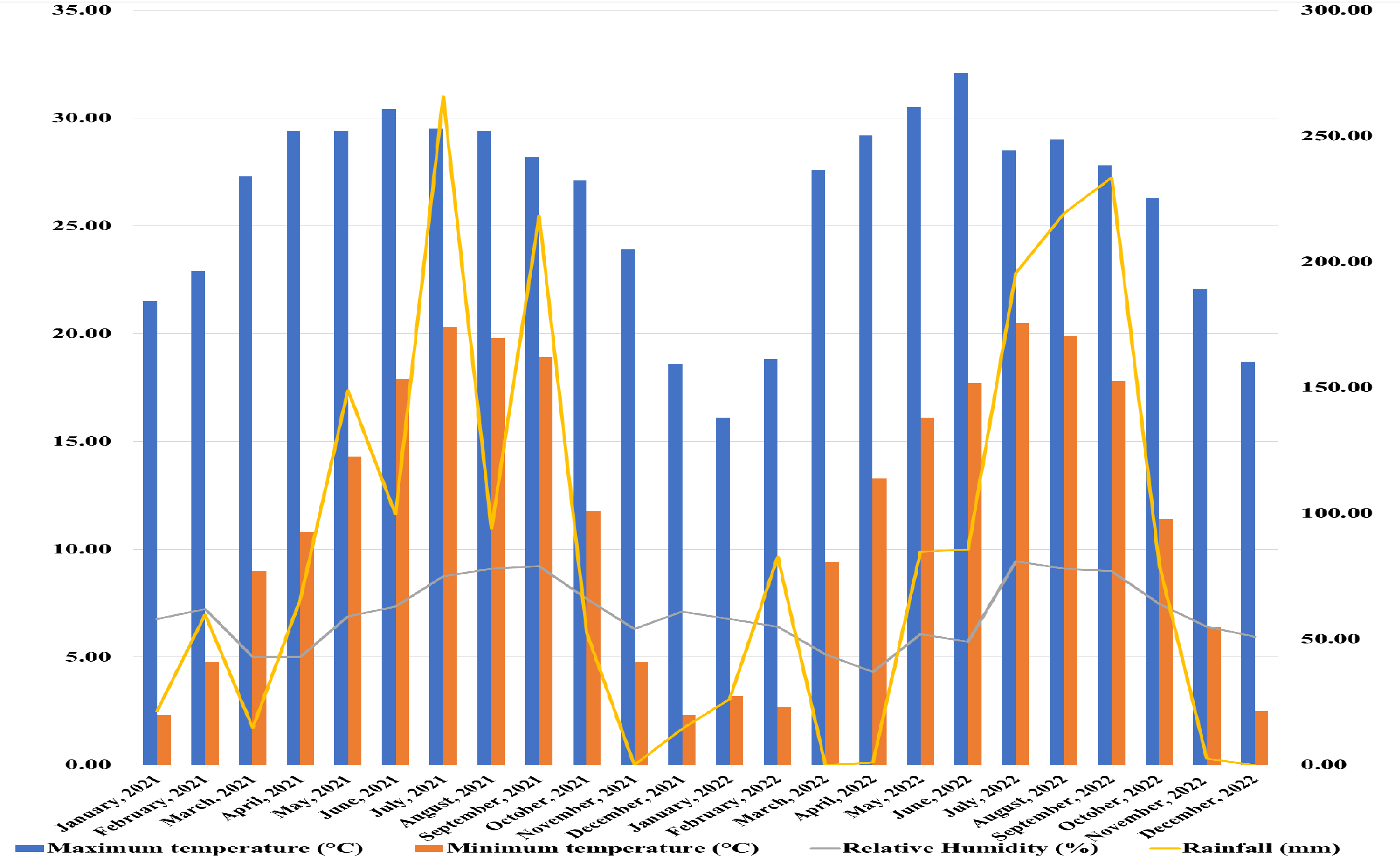


Figure 2: **Mean monthly meteorological data of Dr. Y S Parmar University of Horticulture and Forestry, Nauni, Solan (HP) for the period of experimentation.**

3.1.3 Soils

The important soil physico-chemical properties of the area belong to Typic Eutrochrept at subgroup level according to Soil Taxonomy of USDA. The important physico-chemical properties of the experimental site for 0-30 cm soil depths are presented in Table 1.

Table 1: Physico-chemical properties of soil before the start of experiment

Sr. No.	Parameters	AFS	Open
1	**pH**	7.10	7.19
2	**Moisture content (%)**	6.87	5.02
3	**Electrical conductivity (dS m^{-1})**	0.257	0.189
4	**Bulk density (g cm^{-3})**	1.21	1.34
5	**Organic carbon (%)**	0.51	0.48
6	**Available Nitrogen (kg ha^{-1})**	258.63	255.11
7	**Available Phosphorus (kg ha^{-1})**	41.08	38.09
8	**Available Potassium (kg ha^{-1})**	205.79	201.26

3.2 EXPERIMENTAL METHODOLOGY

The study was conducted with two structural and functional components *viz*., wild pomegranate as woody perennial and lemongrass (*Cymbopogon citratus*) as intercrop. In present experiment, the impact of different organic manures and inorganic fertilizers on the growth and yield parameters of lemongrass, growing along with wild pomegranate was studied.

3.2.1 Structural components

A. Tree species

Tree species	:	Wild pomegranate (*Punica granatum*)
Spacing	:	4 m × 4 m (row to row)
		2 m × 2 m (Plant to Plant)
Direction	:	East-West direction
Year of planting	:	July, 2020
Plant geometry	:	East-West direction

B. Medicinal and aromatic plant

Species	:	Lemongrass (*Cymbopogon citratus*)
Spacing	:	30 cm × 30 cm
Plot size	:	4 m × 2 m
Planting of slips	:	June, 2021

3.2.2 Fertilizer treatments

T_1	:	Recommended dose of nitrogen (RDN for lemon grass i.e., 120 kg ha^{-1} $year^{-1}$)
T_2	:	FYM (on nitrogen equivalent ratio basis)
T_3	:	Vermicompost (on nitrogen equivalent ratio basis)
T_4	:	Goat manure (on nitrogen equivalent ratio basis)
T_5	:	Jeevamrut @ 500 l/ha (5 %)
T_6	:	FYM and RDN on 50:50 equivalence basis
T_7	:	Vermicompost and RDN on 50:50 equivalence basis
T_8	:	Goat manure and RDN on 50:50 equivalence basis
T_9	:	Jeevamrut and RDN on 50:50 equivalence basis
T_{10}	:	Control (without any fertilizer)

Treatment combinations	:	10
Replications	:	03
Planting conditions	:	02 (Wild pomegranate + Lemongrass; Lemongrass alone)
Total number of plots	:	60
Design	:	RBD (Factorial)

3.2.3 Field preparation

Before planting, the experimental field was fully ploughed with a tractor's assistance, followed by planking. Stones and gravel were physically removed from the field and smoothed out nicely with an enough room for good drainage. After that, the experiment's layout was completed, the plots were set up, and the treatments were distributed in accordance with the experiment's planned layout for the crop.

3.2.4 Planting of slips

The crops were multiplied using rooted slips that were harvested from clumps that had reached full maturity. Clump tops were trimmed at a height of 25 cm, while young roots were exposed by removing the lower brown sheath and old roots were trimmed off to keep the slip between 25 and 30 cm long. Each culm (the root part) contained one to three tillers. Each hole was filled with slips dug about 15 cm deep. The slips of lemongrass were planted at the spacing of 30 cm × 30 cm during the month of June, 2021.

3.2.4 Application of organic manures

Different manures doses *viz.*, T_1: Recommended dose of nitrogen fertilizer viz. nitrogen @ 120 kg ha^{-1} in the form of urea (46 % N) i.e. 2.6 quintal ha^{-1} in four split doses, T_2: FYM (0.5 % N) on N equivalent ratio i.e. 240 quintal ha^{-1}, T_3: Vermicompost (1.75 % N) on N equivalent ratio i.e. 68.57 quintal ha^{-1}, T_4: Goat manure (3 % N) on N equivalent ratio i.e. 40 quintal ha^{-1}, T_5: Jeevamrut @ 500 l/ha applied as soil drench, T_6: FYM and RDN on 50:50 equivalence basis, T_7: Vermicompost and RDN on 50:50 equivalence basis, T_8: Goat manure and RDN on 50:50 equivalence basis, T_9: Jeevamrut and RDN on 50:50 equivalence basis and T_{10} control (without any treatment) were applied to different plots randomly. Manures were evenly spread and thoroughly mixed with soil.

Preparation of Jeevamrut:

Jeevamrut was prepared by dissolving the following ingredients in the ratio as:

INGREDIENTS		QUANTITY
COW DUNG	:	10 kg
COW URINE	:	10 litres
JAGGERY	:	1.5 kg
PULSE FLOUR	:	1.5 kg
LIVE SOIL	:	1 kg
WATER	:	200 litres

Dilution of 5 litres of Jeevamrut in 100 litres of water for the soil application.

Flow chart of preparation of Jeevamrut:

Add fresh cow dung + cow urine in water

⇩

Mix jaggery + pulse flour and live soil in water

⇩

Mix the above both and stir properly for 2-3 min. (morning and evening)

⇩

On fifth day filter the solution and filtrate is ready for soil drench

3.2.5 Gap filling

Gap filling was undertaken immediately at 15 days after planting wherever necessary to maintain uniform plant populations in the experimental area.

3.2.6 After care

The experimental site was visited regularly. The inter-cultural operations such as weeding, hoeing were carried out during the crop growth period to ensure healthy crop stands. Irrigations were applied as and when required.

3.2.7 Crop protection

No major diseases or attack of insect pest was observed during the course of investigation. Field was covered from all the sides with help of net to prevent the crop from the attack of rabbits and other animals.

3.3 OBSERVATIONS RECORDED

3.3.1 Growth parameters of wild Pomegranate

The tree parameters *viz.,* height, collar diameter, number of branches per plant, plant spread and leaf litter of newly planted seedlings of wild pomegranate were recorded during the experiment. In this, 2 plants from each row of the experimental area were selected randomly. The growth parameters were recorded for 2 years (2021-2022).

3.3.1.1 Plant height (cm)

Height of the plant was measured with the help of measuring tape.

3.3.1.2 Collar diameter (cm)

Collar diameter was recorded at 10 cm above ground with the help of digital vernier calliper.

3.3.1.3 Number of primary branches plant^{-1}

Numbers of branches per plant were counted manually.

3.3.1.4 Plant spread (cm)

Plant spread was measured in East-West direction and North-South direction with the help of measuring tape.

3.3.1.5 Leaf litter (g)

Litter trap technique was used to determine the quantity of leaf litter production in wild pomegranate seedlings. Litter traps were constructed with the help of nets before the start of leaf shedding in the month of December. Leaf collector was laid below the plant and covered with the net so as to prevent the litter movement due to wind.

3.3.1.6 Fruit yield (kg/tree)

The fruits from randomly selected trees were collected and weighed.

3.3.2 Growth, yield and quality parameters of lemongrass

During the course of study, following observations were recorded to examine the response of lemongrass to different sources of nutrients under wild pomegranate-based agroforestry system as well as in open condition.

3.3.2.1 Growth and yield parameters of lemongrass:

All the growth attributes as listed below were recorded at each harvest of lemongrass during the period of investigation.

Plate 1: Growth of lemongrass under wild pomegranate based agroforestry system

Plate 2: Growth of lemongrass under open condition

3.3.2.1.1 Plant height (cm)

Height of the twelve randomly selected and labelled plants in each plot was measured by the scale from the soil surface to the upper tip of leaf. Then the average was worked out.

3.3.2.1.2 Number of tillers plant^{-1}

The number of tillers per plant was recorded by counting tillers of the twelve observation plants and then the average was worked out.

3.3.2.1.3 Plant spread E-W and N-S (cm)

The spread of individual plant was measured in East-West and North-South directions.

3.3.2.1.4 Fresh herb yield (Mg ha^{-1})

Harvesting of lemongrass was done at 90 days after planting and subsequent harvesting were done after 90 days gap. Although grass went under dormancy from January to mid-April so growth was completely suspended. Total of four harvesting were taken, two in first year and two in second year. The green herbage yield was weighed after each harvesting separately from each treated plot and converted in Mg ha^{-1}.

3.3.2.1.5 Dry herb yield (Mg ha^{-1})

From the study site, fresh lemongrass leaves were gathered and effect of drying was studied by oven-drying leaves at 45°C.

3.3.2.2 Oil quality parameters of lemon grass

Fresh and dried leaves of lemongrass were cut into small pieces and hydro-distillation was carried out for extraction of oil by using Clevenger-type apparatus for a total period of four hours as per method of Guenther (1950). The extracted essential oils were dried using anhydrous sodium sulphate and stored in sealed vials at low temperature for future use. The oil quality parameters of lemongrass essential oil *viz.*, oil yield, oil percentage, acid values, saponification value, iodine value and compound percentage were analysed using the standard methods (AOAC, 1998)

3.3.2.2.1 Oil yield (kg ha^{-1})

The oil yield was recorded after first harvesting and subsequently second harvesting in both the years from each treated plot separately and converted in kg ha^{-1}.

3.3.2.2.2 Oil percentage (%)

The oil percentage were recorded after each harvesting of lemongrass plants.
Oil percentage (%) = (oil weight) / (sample weight) × 100

3.3.2.2.3 Acid value (mg KOH/g)

100 ml of neutral ethyl alcohol was heated with 10 g of oil sample in a 250 cm^3 beaker until the mixture began to boil. The heat was removed and was titrated with N/10 KOH solution, using two drops of phenolphthalein as indicator with consistent shaking for which a permanent pink colour was obtained at the end point. The Acid value was calculated using the expression:

Acid value = 0.56 × No. of ml. N/10 KOH used.

3.3.2.2.4 Saponification value (mg KOH/g)

2 g of the oil sample was added to a flask with 30 cm^3 of ethanolic KOH attached to a condenser for 30 minutes to ensure the sample was fully dissolved. After cooling the sample, 1cm^3 of phenolphthalein was added and titrated with 0.5 M HCl until a pink endpoint has reached. Saponification value (SV) was calculated from the equation (mg KOH/g)

$$\text{Saponification value} = \frac{(S-B)\,X\,M\,X\,50.1}{sample\ weight}$$

Where;

S = sample titre value, B = Blank titre value,

M = Molarity of the HCl,

56.1 = Molecular weight of KOH.

3.3.2.2.5 Iodine value (gI_2/100g)

Iodine value was estimated following the procedure suggested by Akpan *et al*. (2006). In this method, 0.4 g of the oil was weighed into a conical flask and 20 ml of carbon tetra chloride was added. Then 25 ml of Wij's reagent was added to the flask and mixture was

Plate 3: Chopped lemongrass for oil extraction

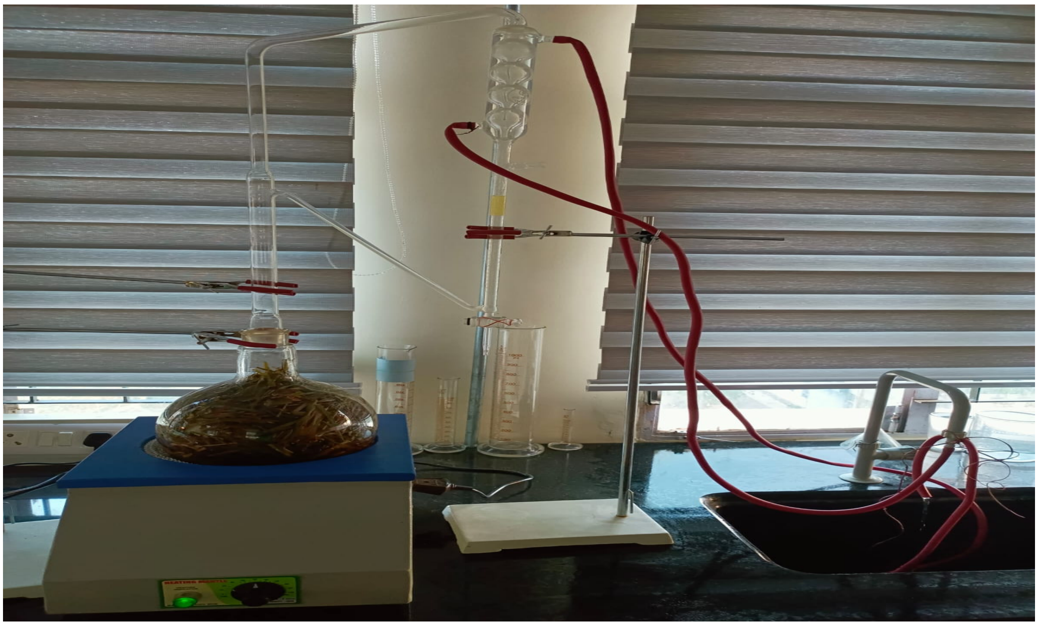


Plate 4: Extraction of lemongrass essential oil by using Clevenger-type apparatus

swirled vigorously after inserting a stopper on the flask. The flask was then kept in the dark for 2 hours 30 minutes. After that, 20 ml of 10 % aqueous potassium iodide and 125 ml distilled water were added by using a measuring cylinder. The content of the flask was titrated with 0.1 M sodium thiosulphate solution until the yellow colours almost disappear. Further, few drops of 1 % starch indicator were added and the titration was continued by adding thiosulphate drop wise, until blue colour disappeared after vigorous shaking. The same procedure was also followed for blank test. The iodine value is given by the expression

$$\text{Iodine value} = \frac{12.69\, C\, (VI - V2)}{M}$$

Where

C	=	Concentration of sodium,
V1	=	Volume of sodium thiosulphate used for blank,
V2	=	Volume of sodium thiosulphate used for determination,
M	=	Mass of the sample.

3.3.2.2.6 Essential oil compound (%)

The essential oil was extracted from the *Cymbopogan citratus* leaves treated with different treatments and GC-MS analysis was carried out with the use of Varian GCMS 4000. The capillary column was of VF-5. The column temperature for GC and GC/MS were 50-180°C at a rate of 5°C/min, transfer line temperature 250°C, carrier gas was helium with a flow rate of 1 ml/min, spilt ratio 1:20, ionization energy 70 eV. The 4 ppm stock solution was prepared by diluting in n Hexane and injected 1µml stock solution in the GCMS. The components of the essential oils were identified by comparison of their mass spectra with those of a computer library or with authentic compounds.

3.3.3 Soil parameters

3.3.3.1 Collection and preparation of soil samples

For soil sampling before planting, randomised soil samples at depth 0-30 cm were collected from the experimental area and mixed together to make composite samples for the analysis. For soil sampling at the end of first year and second year, four soil samples at depth 0-30 cm were collected randomly from each plot separately and composite sample was prepared by mixing the four samples from every plot.

3.3.3.2 Soil processing

Soil samples brought from the field were dried under shade for 15 days after breaking large lumps (if present), with a wooden mallet. It was further ground by pounding with a wooden mallet in such a way that the aggregate particles are broken down to ultimate soil particles. The soil thus processed was sieved through a 2 mm sieve to remove gravel, small stones and coarse roots. The material on the sieve was again ground and sieved till all aggregate particles were fine enough to pass through and only stones and organic residues remain on the sieve. After soil processing, samples were stored in a plastic cover with labelling, out of soil testing laboratory to avoid contamination. For determination of organic carbon, the samples were again passed through 0.2 mm sieve.

3.3.3.3 Laboratory analysis

Soils samples collected from field were analysed for various physical and chemical properties.

3.3.3.3.1 Moisture content (%)

The soil moisture content was determined by Gravimetric method. The samples were collected and dried at 105°C till constant weight achieved (Reynolds, 1970). Soil moisture content was calculated as under:

$$\text{Per cent soil moisture} = \frac{(\text{Fresh weight} - \text{dry weight})}{(\text{Fresh weight})} \text{ X } 100$$

3.3.3.3.2 Bulk density (g cm^{-3})

Soil bulk density was determined by core sampler method (Singh, 1980).

3.3.3.3.3 Soil pH

pH was determined by pH meter in 1:2 soil and water suspension using glass electrodes (Jackson, 1973).

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

EC (dS m^{-1}) was measured in the same 1:2 soil-water suspension prepared for pH determination, using a conductivity meter (Jackson, 1973).

3.3.3.3.5 Soil organic carbon (SOC)

The SOC was estimated by wet digestion method. A known weight of finely powered sample was treated with known volume of standard potassium dichromate ($K_2Cr_2O_7$) and concentrated sulphuric acid (H_2SO_4). The soil is digested by the heat of dilution of H_2SO_4 and organic carbon in the soil is thus oxidized to carbon dioxide. The unused $K_2Cr_2O_7$ was quantified by back titration with ferrous ammonium sulphate using diphenyl amine indicator (Walkley and Black, 1934). There could be incomplete oxidation of the organic matter in this procedure. Therefore, the organic carbon obtained by above method is multiplied by a factor 1.3 based on assumptions that there is 77 per cent recover.

$$\text{OC (\%)} = \frac{(\text{BTC} - \text{STV}) \times \text{Normality of FAS} \times 0.003 \times 100}{\text{Weight of the soil (g)}} \times 1.34$$

Where;

OC = Organic Carbon; BTV = Blank Titre Value; STV = Sample Titre Value

3.3.3.3.6 Available Nitrogen (kg ha^{-1})

Available nitrogen was estimated with the help of alkaline potassium permanganate method (Subbiah and Asija, 1956). Twenty gram of soil was weighed and moistened with distilled water. Then, the weighed soil is added to distillation flask and 100 ml of 0.32 per cent $KMnO_4$ and 100 ml of 2.5 per cent NaOH were added to the distillation flask and cork was fitted immediately. 25 ml of 0.02 N H_2SO_4 was taken in conical flask and 2-3 drops of methyl red indicator was added to the conical flask. After the complete setup hot plate was switched on and 25-30 ml of distillate was collected in the same conical flask containing 0.02 N H_2SO_4. The excess of H_2SO_4 collected in the conical flask was titrated against 0.02 N NaOH and change in colour from pink to yellow was noted as end point.

$$\text{Available Nitrogen (\%)} = \frac{(25 - A) \times 0.00028 \times 100 \times 100}{\text{Weight of Soil}}$$

Where;

A = Volume of 0.02 N NaOH used

ppm of available nitrogen in soil = Available nitrogen (%) × 10000

Available Nitrogen (kg ha^{-1}) = ppm × 2.24

3.3.3.3.7 Available Phosphorus (kg ha^{-1})

Analysis of available phosphorus content (kg ha^{-1}) of soil samples was done as described by Olsen *et al.* (1954). 0.5 g of soil was taken in a 100 ml conical flask followed by the addition of pinch of Darco-G 60 and 20 ml of 0.5 N sodium bicarbonate. The contents were shaken for thirty minutes and filtered to obtain clear filtrate. Now, to 2.5 ml of filtrate add 5 ml of ammonium molybdate and the mixture was shaken thoroughly to remove the CO_2 evolved and 10 ml of distilled water was added to the content. Thereafter, 1 ml of working solution of stannous chloride was added and final volume of 25 ml was made. The contents were mixed thoroughly and the blue colour intensity was measured after five minutes at 660 nm keeping blank appropriately.

ppm of available phosphorus in soil = A × total dilution

Where;

A = Concentration of P read from the standard curve

Available Phosphorus (kg ha^{-1}) = ppm × 2.24

3.3.3.3.8 Available Potassium (kg ha^{-1})

Available potassium was determined with the help of Merwin and Peach method (Merwin and Peach, 1951). 2.5 g of soil was transferred to a 150 ml of conical flask. 25 ml of neutral ammonium acetate solution was added and the contents were shaken for five minutes on electric shaker. The contents of the conical flask were filtered and the filtrate was fed to the atomizer of the flame photometer. The reading was noted and expressed in ppm.

ppm of available potassium in soil = Y × Total dilution

Where;

Y = ppm as read from the standard curve

Available potassium (kg ha^{-1}) = ppm × 2.24

3.4 LAYOUT AND STATISTICAL ANALYSIS

3.4.1 Layout plan of the experiment

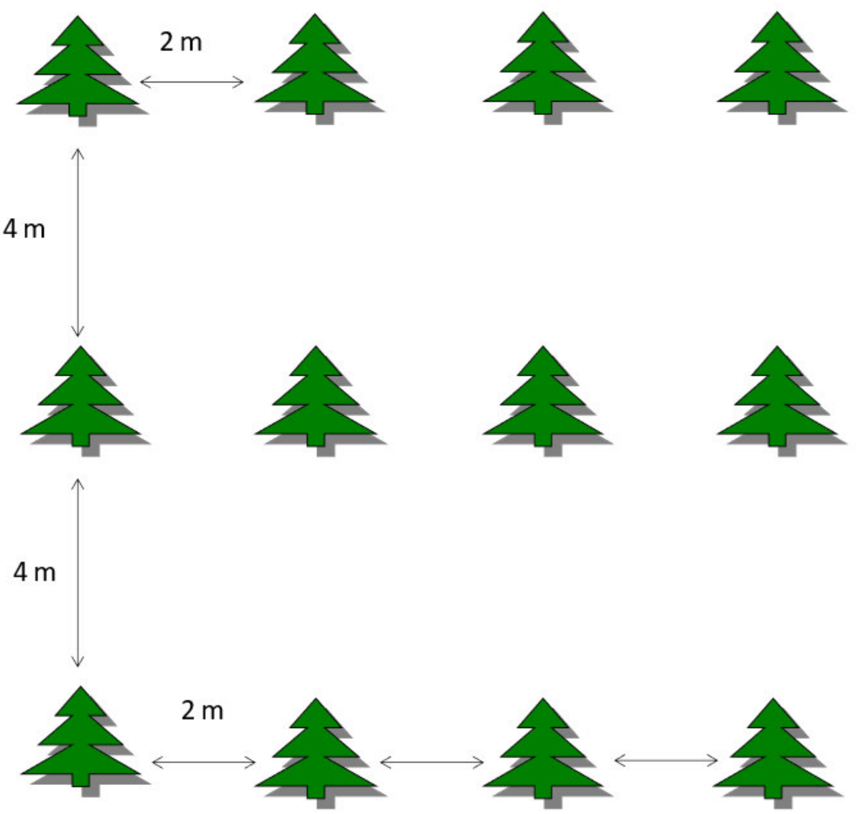


Figure 3: Layout plan of experimental area showing arrangement of components

3.4.2 Statistical analysis

The statistics used to analyse the data from the current study followed the steps indicated by Gomez and Gomez (1984) where, testing the significant differences between the treatment means, the critical difference (CD) at the 5 % level of significance was used.p

Chapter-4

RESULTS AND DISCUSSION

The study entitled "**Effects of organic manures on growth, yield and oil quality parameters of lemon grass under wild pomegranate based agroforestry system"** was conducted during the year 2021-2022 in the Department of Silviculture and Agroforestry, Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. The results obtained from the present investigation have been presented and aptly discussed in this chapter under different headings given below:

4.1 Effect of organic manures on growth, yield and oil quality parameters of lemongrass.

4.2 Growth parameters of wild pomegranate.

4.3 Effect of organic manures on soil physico-chemical properties.

4.4 Bio-economic appraisal of wild pomegranate-based agroforestry.

4.1 TO STUDY THE EFFECT OF ORGANIC MANURES ON GROWTH, YIELD AND OIL QUALITY PARAMETERS OF LEMONGRASS

4.1.1. Plant height (cm)

Perusal of data presented in Table 2 revealed that year, treatment and planting condition had significant effect on plant height. Pertaining to the year 2021, among different planting condition highest plant height was recorded in C_2 (61.71 cm) and lowest was recorded in C_1 (60.01 cm). Among different manure treatments, maximum plant height was observed in treatment T_8 (77.43 cm) whereas plant height was minimum in T_{10} (46.39 cm). Under the interaction between the treatment and planting condition (T×C); maximum plant height was recorded in treatment combination T_8C_2 (77.87 cm) while minimum plant height was recorded in$T_{10}C_1$ (45.85 cm).

In the year 2022, among two planting conditions plant height was highest in C_2 (107.07 cm) and lowest in C_1 (103.89 cm). Treatment, effect revealed that maximum plant height was recorded under treatment T_8 (133.96 cm) whereas minimum plant height was recorded under T_{10} (83.58 cm). Combined effect of treatment and planting condition (T×C) showed that treatment combination T_8C_2 (135.42 cm) was having highest plant height while lowest was found in $T_{10}C_1$ (82.08 cm).

Pooled data of both the years showed that among different planting condition, open condition (84.39 cm) recorded higher plant height when compared to agroforestry system (81.95 cm). Under different treatments, T_8 (105.69 cm) recorded highest plant height and T_{10} (64.99 cm) lowest plant height. Cumulative effect of treatment and condition (T×C) depicts that treatment combination T_8C_2 (106.65 cm) recorded maximum plant height and minimum plant height was recorded in $T_{10}C_1$ (63.97 cm).

Further it has been noticed that plant height was higher in year 2022 (105.48 cm) as compared to year 2021 (60.86 cm). Interaction between year and planting condition (Y×C); year and treatment (Y×T); year, treatment and planting condition (Y×T×C) registered no significant effect on plant height.

Plant height was reported maximum where integration of organic manures was done with inorganic fertilizers. This might be due to fertilizer source that fulfilled the requirements at early growth stages, while organic manures facilitated crop at later stages by providing uniform and continuous supply of nutrients which has a role in cell division and other physiological processes. Similar results were reported by Nandapure *et al*. (2020), who reported significant increase in the plant height of java citronella grass when application of organic nutrients was combined with chemical fertilizers. Also, the results are consistent with the findings of Abbas *et al*. (2019) that confirmed increase in plant height with integrated nutrient (organic and inorganic) application in okra plant. The results also fit well with the findings of Mubarok *et al*. (2017), Devi *et al*. (2018) and Namdeo *et al*. (2021), where integrated nutrient management showed significant impact on plant height.

4.1.2 Number of tillers per plant

Data pertaining to the effect of year, treatment and planting condition on number of tillers have been presented in Table 3. It could be gleaned from data that planting condition, treatment and year have significant effect on the number of tillers. During the year 2021, among different treatments minimum number of tillers were observed in T_{10} (34.33) and maximum in T_8 (70.71). Counting to the different planting condition lower number of tillers were observed in C_1 (51.27) followed by C_2 (52.70). Cumulative effect of treatment and planting condition (T×C) recorded minimum number of tillers in $T_{10}C_1$ (33.50) and maximum in T_8C_2 (70.71).

Table 2: Effect of organic manures and planting conditions on plant height (cm) of lemongrass

Treatments / Conditions	2021 (Y_1)			2022 (Y_2)			Pooled		
	Agroforestry system (C_1)	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**
T_1	50.90	53.01	**51.96**	91.17	94.33	**92.75**	71.03	73.67	**72.35**
T_2	55.62	57.78	**56.70**	97.17	100.20	**98.68**	76.39	78.99	**77.69**
T_3	58.21	60.41	**59.31**	103.50	106.71	**105.11**	80.85	83.56	**82.21**
T_4	62.28	64.41	**63.34**	104.83	107.91	**106.37**	83.56	86.16	**84.86**
T_5	48.49	50.75	**49.62**	86.17	89.45	**87.81**	67.33	70.10	**68.71**
T_6	68.42	69.50	**68.96**	112.17	115.10	**113.63**	90.29	92.30	**91.29**
T_7	70.60	72.83	**71.71**	122.84	125.90	**124.37**	96.72	99.36	**98.04**
T_8	76.99	77.87	**77.43**	132.50	135.42	**133.96**	104.74	106.65	**105.69**
T_9	62.72	63.61	**63.16**	106.50	110.62	**108.56**	84.61	87.12	**85.86**
T_{10}	45.85	46.94	**46.39**	82.08	85.08	**83.58**	63.97	66.01	**64.99**
Mean	**60.01**	**61.71**	**60.86**	**103.89**	**107.07**	**105.48**	**81.95**	**84.39**	
$CD_{0.05}$									
Year	0.88								
Treatment	1.96								
Condition	0.88								
Year × Treatment	Non-significant								
Year × Condition	Non-significant								
Treatment × Condition	2.77								
Year × Treatment × Condition	Non-significant								

T_1: Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis), **T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis, **T_8**: Goat manure and RDN on 50:50 equivalence basis, **T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

During the year 2022, treatment effect revealed that lowest number of tillers were recorded under treatment T_{10} (43.35) whereas highest number of tillers were recorded under T_8 (83.05). Under different planting condition; minimum number of tillers were recorded in C_1 (61.18) and maximum number of tillers were recorded in C_2 (64.81). Interaction between the treatment and planting condition (T×C) showed that treatment combination $T_{10}C_1$ (41.82) were having lowest number of tillers while highest number of tillers were found in T_8C_2 (84.89).

Pooled data of both the years revealed that among different treatments, T_{10} (38.84) recorded minimum and T_8 (76.58) maximum number of tillers. Under different planting condition, open condition showed higher (58.75) number of tillers when compared to agroforestry system (56.22). Cumulative effect of treatment and condition (T×C) depicts that treatment combination $T_{10}C_1$ (37.66) recorded minimum number of tillers and maximum number of tillers were recorded in T_8C_2 (77.80).

In general, number of tillers were lower in the 2021 (51.98) than the year 2022 (62.99). Considering the interaction effect of year and planting condition (Y×C) revealed that number of tillers were lowest in Y_1C_1 (51.27) while highest under Y_2C_2 (64.81). Whereas, interaction between year and treatment (Y×T) as well as year, treatment and planting condition (Y×T×C) registered no significant effect on number of tillers.

The results revealed that highest number of tillers were observed in the treatment using 50 % RDN through inorganic fertilizer and 50 % RDN through organic manure. Similar results were proposed by Lalito *et al*. (2018) which showed superiority of integrated nutrient management in increasing growth parameters over sole application of organic manures or inorganic fertilizers. This may be because soil under integrated nutrient management had a sizable amount of soil organic carbon as well as micro and macronutrients that were necessary for the sustainable vegetative growth (Zahid *et al*., 2022). The results from the present study also substantiate the previous findings of Premathilake *et al*. (2018), where they recoded maximum number of tillers in lemongrass when application of inorganic fertilizer was combined with the organic manures. The increase in the number of tillers may be attributed to the readily availability of nutrients from inorganic fertilizer and increase in water holding capacity as well as soil moisture due to organic manures application.

Table 3: Effect of organic manures and planting conditions on number of tillers per plant of lemongrass

Treatments / Conditions	1st Year			2nd Year			Pooled		
	Agroforestry system (C_1)	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**
T_1	44.04	45.91	**44.98**	51.97	55.39	**53.68**	48.00	50.65	**49.33**
T_2	46.71	47.83	**47.27**	57.04	60.76	**58.90**	51.88	54.29	**53.09**
T_3	50.22	52.22	**51.22**	60.20	63.54	**61.87**	55.21	57.88	**56.54**
T_4	53.26	55.04	**54.15**	62.51	67.55	**65.03**	57.88	61.30	**59.59**
T_5	38.47	40.45	**39.46**	48.22	51.63	**49.92**	43.35	46.04	**44.69**
T_6	61.10	62.57	**61.83**	72.07	75.32	**73.70**	66.59	68.94	**67.76**
T_7	64.58	66.43	**65.51**	74.21	78.43	**76.32**	69.39	72.43	**70.91**
T_8	69.52	70.71	**70.11**	81.22	84.89	**83.05**	75.37	77.80	**76.58**
T_9	51.27	50.64	**50.95**	62.52	65.76	**64.14**	56.89	58.20	**57.54**
T_{10}	33.50	35.15	**34.33**	41.82	44.88	**43.35**	37.66	40.01	**38.84**
Mean	**51.27**	**52.70**	**51.98**	**61.18**	**64.81**	**62.99**	**56.22**	**58.75**	
$CD_{0.05}$									
Year	0.53								
Treatment	1.19								
Condition	0.53								
Year × Treatment	Non-significant								
Year × Condition	0.75								
Treatment × Condition	1.68								
Year × Treatment × Condition	Non-significant								

T_1: Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis), **T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis, **T_8**: Goat manure and RDN on 50:50 equivalence basis, **T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

4.1.3 Plant spread (cm)

The contents of the data presented in Table 4 revealed that year, treatment and planting condition had significant effect on plant spread. During the year 2021, among different planting conditions, maximum plant spread was recorded in C_2 (49.44 cm) while minimum in C_1 (45.94 cm), however among different doses of manures it was highest in T_8 (60.43 cm) whereas lowest in T_{10} (36.54 cm). Meanwhile considering the interaction effect between the treatment and planting condition (T×C), maximum plant spread was recorded in treatment combination T_8C_2 (62.21 cm) and minimum in $T_{10}C_1$ (34.77 cm).

In the data recorded for the year 2022 same trends were observed, where among different planting conditions; highest plant spread was recorded in C_2 (85.94 cm) and lowest in C_1 (80.90 cm). Consequently, treatment effect revealed that maximum plant spread was recorded under T_8 (100.54 cm) and minimum under T_{10} (68.33 cm), however combined effect of treatment and planting condition (T×C) portrayed that treatment combination T_8C_2 (103.08 cm) was having highest while $T_{10}C_1$ (65.67 cm) recorded the lowest plant spread, respectively.

Pooled data of both the years showed that among different planting condition, open condition (67.69 cm) showed comparatively higher plant spread when compared to agroforestry system (63.42 cm). Similarly, under different treatments, T_8 (80.48 cm) recorded highest plant spread and T_{10} (52.44 cm) recorded the lowest plant spread. Cumulative effect of treatment and condition (T×C) depicted that treatment combination T_8C_2 (82.65 cm) recorded maximum plant spread and $T_{10}C_1$ (50.22 cm) recorded the minimum.

Further it has been noticed that higher plant spread was recorded in year 2022 (83.42 cm) as compared to 2021 (47.69 cm). The composite effect of year and treatment (Y×T) recorded; minimum plant spread in year 2021 under Y_1T_{10} (36.54 cm) and maximum in year 2022 under Y_2T_8 (100.54 cm). Lastly, interaction between year and planting condition (Y×C); year, treatment and planting condition (Y×T×C) laid no significant effect on plant spread.

The results support the previous findings of Pramod *et al*. (2020) and Devkota *et al*. (2021), they confirmed increase in plant spread with integrated nutrient management. The increased plant spread may have been caused by an improvement in morphological parameters brought on by the use of inorganic fertilisers with organic manure. Additionally,

Table 4: Effect of organic manures and planting conditions on plant spread (cm) of lemongrass

Treatments / Conditions	2021 (Y_1)			2022 (Y_2)			Pooled		
	Agroforestry system (C_1)	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**
T_1	40.63	44.21	**42.42**	74.05	79.00	**76.53**	57.34	61.60	**59.47**
T_2	44.19	47.69	**45.94**	78.65	83.69	**81.17**	61.42	65.69	**63.56**
T_3	46.76	50.26	**48.51**	82.56	87.57	**85.06**	64.66	68.91	**66.79**
T_4	49.26	52.68	**50.97**	85.79	90.73	**88.26**	67.53	71.71	**69.62**
T_5	38.49	41.99	**40.24**	71.04	76.08	**73.56**	54.77	59.04	**56.90**
T_6	50.90	54.32	**52.61**	86.73	91.65	**89.19**	68.81	72.98	**70.90**
T_7	54.83	58.33	**56.58**	92.58	97.63	**95.10**	73.70	77.98	**75.84**
T_8	58.65	62.21	**60.43**	97.99	103.08	**100.54**	78.32	82.65	**80.48**
T_9	40.96	44.38	**42.67**	73.92	78.94	**76.43**	57.44	61.66	**59.55**
T_{10}	34.77	38.31	**36.54**	65.67	71.00	**68.33**	50.22	54.65	**52.44**
Mean	**45.94**	**49.44**	**47.69**	**80.90**	**85.94**	**83.42**	**63.42**	**67.69**	
$CD_{0.05}$									
Year	0.80								
Treatment	1.78								
Condition	0.80								
Year × Treatment	2.52								
Year × Condition	Non-significant								
Treatment × Condition	2.52								
Year × Treatment × Condition	Non-significant								

T_1: Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis), **T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis, **T_8**: Goat manure and RDN on 50:50 equivalence basis, **T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

using organic manures with inorganic fertilisers has a longer-lasting effect on plant species performance and improves the build-up of organic matter in soils. This has favourable effects on the ability of plants to acquire and absorb fundamental nutrients like nitrogen and phosphorus, as well as their availability which results in better growth. The results share similarities with the Punam *et al.* (2012) who demonstrated positive impact of nutrient application on plant spread when compared to plant spread under control. Another possible explanation for this could be increased soil nutrient uptake, particularly of iron and magnesium, which results in increased photosynthetic area and therefore better growth (Kumar *et al.*, 2016).

4.1.4 Fresh herb yield (Mg ha^{-1})

It is evident from the data presented in Table 5 that planting condition, treatment and year had significant effect on fresh herb yield. During the year 2021, among different doses of manures; minimum fresh herb yield was observed in T_{10} (9.33 Mg ha^{-1}) and maximum in T_8 (15.72 Mg ha^{-1}). While counting to the different planting condition, higher fresh herb yield was recorded in C_2 (13.44 Mg ha^{-1}) followed by C_1 (12.26 Mg ha^{-1}). However, the cumulative effect of treatment and planting condition (T×C), recorded minimum fresh herb yield in $T_{10}C_1$ (8.84 Mg ha^{-1}) and maximum in T_8C_2 (16.32 Mg ha^{-1}).

In the year 2022 same trends were noticed, where relatively lower fresh herb yield was recorded in C_1 (21.67 Mg ha^{-1}) and higher fresh herb yield was recorded in C_2 (22.99 Mg ha^{-1}). Treatment effect revealed that minimum fresh herb yield was recorded under treatment T_{10} (14.92 Mg ha^{-1}) whereas maximum fresh herb yield was recorded under T_8 (26.46 Mg ha^{-1}). Combined effect of treatment and planting condition (T×C) showed that treatment combination $T_{10}C_1$ (27.05 Mg ha^{-1}) was having lowest fresh herb yield while highest fresh herb yield was found in T_8C_2 (14.23 Mg ha^{-1}).

Pooled data of both the year reflects that among different planting conditions; higher fresh herb yield was recorded in C_2 (18.21 Mg ha^{-1}) and lower in C_1 (16.96 Mg ha^{-1}). However, under different nutrient doses, T_8 (21.09 Mg ha^{-1}) recorded highest fresh herb yield while T_{10} (12.13 Mg ha^{-1}) recorded lowest fresh herb yield. The yield reduction in intercropping system is a common phenomenon (Agenuhu *et al.,* 2006, Xu *et al*., 2008). Similar results were reported by Kar *et al*. (2019) and Keprate (2021) and Gautam (2023). This could be attributed to more vigorous growth with favourable space, air, sunlight and

Table 5: Effect of organic manures and planting conditions on fresh herb yield (Mg/ha) of lemongrass

Treatments / Conditions	2021 (Y_1)			2022 (Y_2)			Pooled		
	Agroforestry system (C_1)	Open (C_2)	Mean	Agroforestry system (C_1)	Open (C_2)	Mean	Agroforestry system (C_1)	Open (C_2)	Mean
T_1	11.07	12.27	**11.67**	20.41	21.96	**21.18**	15.74	17.11	**16.43**
T_2	11.68	12.88	**12.28**	21.08	22.55	**21.81**	16.38	17.71	**17.05**
T_3	12.30	13.49	**12.90**	21.67	23.18	**22.43**	16.98	18.34	**17.66**
T_4	13.14	14.34	**13.74**	22.73	24.16	**23.44**	17.93	19.25	**18.59**
T_5	9.95	11.15	**10.55**	19.48	21.21	**20.35**	14.72	16.18	**15.45**
T_6	13.64	14.84	**14.24**	23.67	24.76	**24.21**	18.66	19.80	**19.23**
T_7	14.35	15.55	**14.95**	24.81	25.90	**25.35**	19.58	20.72	**20.15**
T_8	15.13	16.32	**15.72**	25.87	27.05	**26.46**	20.50	21.68	**21.09**
T_9	12.51	13.71	**13.11**	22.73	23.50	**23.11**	17.62	18.60	**18.11**
T_{10}	8.84	9.83	**9.33**	14.23	15.61	**14.92**	11.54	12.72	**12.13**
Mean	**12.26**	**13.44**	**12.85**	**21.67**	**22.99**	**22.33**	**16.96**	**18.21**	
$CD_{0.05}$									
Year	0.06								
Treatment	0.14								
Condition	0.06								
Year × Treatment	Non-significant								
Year × Condition	Non-significant								
Treatment × Condition	0.19								
Year × Treatment × Condition	NS								

T_1: Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis), **T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis, **T_8**: Goat manure and RDN on 50:50 equivalence basis, **T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

availability of nutrients or less interspecific completion. Whereas, cumulative effect of treatment and condition (T×C) depicts that treatment combination T_8C_2 (21.68 Mg ha^{-1}) recorded maximum fresh herb yield and minimum fresh herb yield was recorded in $T_{10}C_1$ (11.54 Mg ha^{-1}).

In general, fresh herb yield was higher in year 2022 (22.33 Mg ha^{-1}) than the year 2021 (12.85 Mg ha^{-1}). Whereas, interaction effect between the year and treatment (Y×T), year and condition (Y×C) as well as year, treatment and planting condition (Y×T×C) were found to be non-significant.

The findings are in agreement with the Smitha *et al*. (2021) who observed an increase in fresh herb production in *Bacopa monnieri* (Brahmi) by combining the application of organic manures with inorganic fertiliser sources. The higher fresh herb yield with integrated application of organic manures and chemical fertilizers is due to more contribution of yield attributes like plant height, number of tillers and plant spread. The results are also in line with the findings of Sharada and Sujathamma (2018) and Elankavi (2017). The possible reason for increase in the fresh herb yield is that combining manures and chemical fertilisers promotes the mineralization of nutrients and preserves the field's soil moisture availability. Additionally, it gives the soil the best possible physical condition by enhancing porosity and water holding capacities, which multiply root density. Increased root development increases nutrient uptake and yield. Similar results were reported by Parewa *et al*. (2019) and Kumar *et al*. (2020), where yield under integrated nutrient management was superior when compared to organic and inorganic nutrient alone.

4.1.6 Dry herb yield (Mg ha^{-1})

The data on the dry herb yield as influenced by imposition of different year, manure treatments and planting conditions, presented in the Table 6. It indicates significant effect of year, treatment and planting conditions on dry herb yield. Pertaining to the year 2021, among different planting conditions higher dry herb yield was recorded in C_2 (5.09 Mg ha^{-1}) and lower was recorded in C_1 (4.64 Mg ha^{-1}). Among different manure treatments maximum dry herb yield was observed in treatment T_8 (5.96 Mg ha^{-1}) whereas dry herb yield was minimum in T_{10} (3.53 Mg ha^{-1}). Under the interaction between the treatment and planting condition (T×C); maximum dry herb yield was recorded in treatment combination T_8C_2 (6.18 Mg ha^{-1}) while minimum dry herb yield was recorded in$T_{10}C_1$ (3.35 Mg ha^{-1}).

In the year 2022, among planting two condition highest dry herb yield was recorded in C_1 (8.21 Mg ha^{-1}) and lowest dry herb yield was recorded in C_2 (8.71 Mg ha^{-1}). Treatment, effect revealed that maximum dry herb yield was recorded under treatment T_8 (10.02 Mg ha^{-1}) whereas minimum dry herb yield was recorded under T_{10} (5.65 Mg ha^{-1}). Combined effect of treatment and planting condition (T×C) showed that treatment combination T_8C_2 (10.25 Mg ha^{-1}) was having highest dry herb yield while lowest was found in $T_{10}C_1$ (5.39 Mg ha^{-1}).

Pooled data of both the years showed that among different planting condition, open condition recorded higher (6.90 Mg ha^{-1}) dry herb yield when compared to agroforestry system (6.43 Mg ha^{-1}). Under different treatments, T_8 (7.99 Mg ha^{-1}) recorded maximum dry herb yield and T_{10} (4.59 Mg ha^{-1}) minimum dry herb yield. Cumulative effect of treatment and condition (T×C) depicts that treatment combination T_8C_2 (8.21 Mg ha^{-1}) recorded highest dry herb yield and lowest dry herb yield was recorded in $T_{10}C_1$ (4.37 Mg ha^{-1}).

Further it has been noticed that higher (8.46 Mg ha^{-1}) dry herb yield was recorded in year 2022 as compared to year 2021 (4.87 Mg ha^{-1}). Interaction between year and planting condition (Y×C) had no significant effect on dry herb yield. Also, interaction between year and treatment (Y×T) as well as year, treatment and planting condition (Y×T×C) registered no significant effect on dry herb yield.

The results are consistent with the findings of Elza *et al*. (2014) in *Achillea millefolium* and El-Sayed *et al*. (2018) in *Citronella.* The plausible reason for increase in the dry herb yield may be because the integration of inorganic sources of nutrients and organic manures ensured the readily availability of nutrients for initial requirement through the inorganic source and a slow pace, long term availability of nutrients through organic manures. Because nutrients were continuously available, plants were able to absorb more of them, which increased the amount of dry matter they accumulated throughout all phases of growth, increasing the dry weight of the herb both per plant and per hectare. Similar results were reported by AL-mansour *et al*. (2017) and Ejigu *et al*. (2021), where dry herb yield under integrated nutrient management was superior when compared to organic and inorganic nutrient alone.

Table 6: Effect of organic manures and planting conditions on dry herb yield (Mg/ha) of lemongrass

Treatments / Conditions	2021 (Y_1)			2022 (Y_2)			Pooled		
	Agroforestry system (C_1)	Open (C_2)	Mean	Agroforestry system (C_1)	Open (C_2)	Mean	Agroforestry system (C_1)	Open (C_2)	Mean
T_1	4.19	4.65	**4.42**	7.73	8.32	**8.02**	5.96	6.48	**6.22**
T_2	4.42	4.88	**4.65**	7.98	8.54	**8.26**	6.20	6.71	**6.46**
T_3	4.66	5.11	**4.88**	8.21	8.78	**8.49**	6.43	6.95	**6.69**
T_4	4.98	5.43	**5.20**	8.61	9.15	**8.88**	6.79	7.29	**7.04**
T_5	3.77	4.22	**4.00**	7.38	8.04	**7.71**	5.57	6.13	**5.85**
T_6	5.17	5.62	**5.39**	8.97	9.38	**9.17**	7.07	7.50	**7.28**
T_7	5.44	5.89	**5.66**	9.40	9.81	**9.60**	7.42	7.85	**7.63**
T_8	5.73	6.18	**5.96**	9.80	10.25	**10.02**	7.76	8.21	**7.99**
T_9	4.74	5.19	**4.97**	8.61	8.90	**8.76**	6.68	7.05	**6.86**
T_{10}	3.35	3.72	**3.53**	5.39	5.91	**5.65**	4.37	4.82	**4.59**
Mean	**4.64**	**5.09**	**4.87**	**8.21**	**8.71**	**8.46**	**6.43**	**6.90**	
$CD_{0.05}$									
Year	0.06								
Treatment	0.14								
Condition	0.06								
Year × Treatment	Non-significant								
Year × Condition	Non-significant								
Treatment × Condition	0.19								
Year × Treatment × Condition	Non-significant								

T_1: Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis), **T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis, **T_8**: Goat manure and RDN on 50:50 equivalence basis, **T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

4.1.7 Oil percentage (%)

4.1.7.1 Fresh leaves oil percentage (%)

The exposition of values in Table 7 confirmed that year, treatment and planting condition had significant effect on fresh leaves oil percentage, while their interaction failed to bring any perceptible difference in oil percentage. In year 2021, among planting conditions, maximum oil percentage was recorded in C_2 (0.37 %) and minimum in C_1 (0.36 %), however among different treatments it was highest in T_8 (0.46 %) whereas lowest in T_{10} (0.27 %).

Continuing to the year 2022 same trends were noticed, where among planting conditions higher oil percentage was recorded in C_2 (0.42 %) and lower in C_1 (0.40 %). Consequently, treatment effect revealed that maximum oil percentage was recorded under T_8 (0.50 %) and minimum under T_{10} (0.30 %).

Pooled data of both the years showed that among different planting condition, open condition (0.39 %) showed better oil percentage when compared to agroforestry system (0.38 %). Similarly, under different treatments, T_8 (0.48 %) recorded highest oil percentage and T_{10} (0.28 %) recorded the lowest oil percentage. Further it has been noticed that higher oil percentage was recorded in year 2022 (0.41 %) as compared to 2021 (0.37 %).

Similar trend was recorded by the Premathilake *et al.* (2018) where highest oil percentage was recorded under combine application of the organic manure and inorganic fertilizer followed by organic manure, inorganic fertilizers and lowest oil percentage was recorded under control. The results are in conformity with the findings of Punam *et al*. (2012) and Gajbhiye *et al.* (2013), they reported that oil content of *lemongrass* positively responded to the application of fertilizers compared to the control. Kumar *et al.* (2015) and Sefaoglu *et al.* (2021) also reported an increase in the oil percentage of coriander and sunflower respectively under integrated nutrient management.

4.1.7.2 Dry leaves oil percentage (%)

A critical look at the data presented in Table 8 accentuates that year, treatment, planting condition and their interaction laid significant influence on dry leaves oil percentage. Pertaining to the year 2021, among different planting conditions, maximum oil percentage

Table 7: Effect of organic manures and planting conditions on fresh leaves oil percentage (%) of lemongrass

Conditions / Treatments	2021 (Y_1)			2022 (Y_2)			Pooled		
	Agroforestry system (C_1)	Open (C_2)	Mean	Agroforestry system (C_1)	Open (C_2)	Mean	Agroforestry system (C_1)	Open (C_2)	Mean
T_1	0.33	0.33	**0.33**	0.35	0.36	**0.35**	0.34	0.35	**0.34**
T_2	0.34	0.34	**0.34**	0.37	0.39	**0.38**	0.36	0.37	**0.36**
T_3	0.36	0.37	**0.37**	0.41	0.42	**0.41**	0.39	0.40	**0.39**
T_4	0.39	0.40	**0.39**	0.43	0.45	**0.44**	0.41	0.43	**0.42**
T_5	0.31	0.32	**0.31**	0.34	0.35	**0.34**	0.32	0.33	**0.33**
T_6	0.39	0.40	**0.39**	0.44	0.46	**0.45**	0.41	0.43	**0.42**
T_7	0.42	0.44	**0.43**	0.47	0.49	**0.48**	0.45	0.46	**0.45**
T_8	0.45	0.46	**0.46**	0.50	0.51	**0.50**	0.47	0.49	**0.48**
T_9	0.37	0.39	**0.38**	0.41	0.44	**0.42**	0.39	0.41	**0.40**
T_{10}	0.27	0.28	**0.27**	0.29	0.30	**0.30**	0.28	0.29	**0.28**
Mean	**0.36**	**0.37**	**0.37**	**0.40**	**0.42**	**0.41**	**0.38**	**0.39**	
$CD_{0.05}$									
Year	0.01								
Treatment	0.01								
Condition	0.01								
Year × Treatment	Non-significant								
Year × Condition	Non-significant								
Treatment × Condition	Non-significant								
Year × Treatment × Condition	Non-significant								

T_1: Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis), **T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis, **T_8**: Goat manure and RDN on 50:50 equivalence basis, **T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

Table 8: Effect of organic manures and planting conditions on dry leaves oil percentage (%) of lemongrass

Conditions / Treatments	2021 (Y_1)			2022 (Y_2)			Pooled		
	Agroforestry system (C_1)	Open (C_2)	Mean	Agroforestry system (C_1)	Open (C_2)	Mean	Agroforestry system (C_1)	Open (C_2)	Mean
T_1	0.86	0.87	**0.87**	0.93	0.96	**0.94**	0.89	0.91	**0.90**
T_2	0.87	0.91	**0.89**	1.02	1.03	**1.03**	0.95	0.97	**0.96**
T_3	0.96	0.96	**0.96**	1.05	1.10	**1.08**	1.01	1.03	**1.02**
T_4	1.02	1.02	**1.02**	1.11	1.18	**1.15**	1.07	1.10	**1.08**
T_5	0.80	0.82	**0.81**	0.88	0.92	**0.90**	0.84	0.87	**0.85**
T_6	1.01	1.06	**1.04**	1.14	1.21	**1.17**	1.08	1.13	**1.10**
T_7	1.14	1.16	**1.15**	1.23	1.28	**1.25**	1.18	1.22	**1.20**
T_8	1.19	1.22	**1.20**	1.31	1.37	**1.34**	1.25	1.29	**1.27**
T_9	0.99	1.02	**1.01**	1.07	1.16	**1.12**	1.03	1.09	**1.06**
T_{10}	0.73	0.71	**0.72**	0.77	0.75	**0.76**	0.75	0.73	**0.74**
Mean	**0.96**	**0.98**	**0.97**	**1.05**	**1.10**	**1.07**	**1.00**	**1.04**	
$CD_{0.05}$									
Year	0.01								
Treatment	0.02								
Condition	0.01								
Year × Treatment	0.03								
Year × Condition	0.01								
Treatment × Condition	0.03								
Year × Treatment × Condition	0.04								

T_1: Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis), **T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis, **T_8**: Goat manure and RDN on 50:50 equivalence basis, **T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

was recorded in C_2 (0.98 %) while minimum in C_1 (0.96 %), however among different doses of nutrients it was highest in T_8 (1.20 %) whereas lowest in T_{10} (0.72 %). Meanwhile considering the interaction effect between the treatment and planting condition (T×C), maximum oil percentage was recorded in treatment combination T_8C_2 (1.22 %) and minimum in $T_{10}C_1$ (0.73 %).

In the data recorded for the year 2022 same trends were observed, where among planting conditions higher oil percentage was recorded in C_2 (1.10 %) compared to C_1 (1.05 %). Consequently, treatment effect revealed that maximum oil percentage was recorded under T_8 (1.34 %) and minimum under T_{10} (0.76 %), however combined effect of treatment and planting condition (T×C) portrayed that treatment combination T_8C_2 (1.37 %) was having highest while $T_{10}C_1$ (0.77 %) recorded the lowest oil percentage, respectively.

Pooled data of both the years showed that among planting conditions, open condition (1.04 %) showed higher oil percentage when compared to agroforestry system (1.00 %). Similarly, under different treatments, T_8 recorded highest oil percentage (1.27 %) and T_{10} recorded the lowest (0.74 %). Cumulative effect of treatment and condition (T×C) depicted that treatment combination T_8C_2 recorded maximum (1.29 %) oil percentage and $T_{10}C_1$ recorded the minimum (0.75 %).

Further it has been noticed that highest oil percentage was recorded in year 2022 (1.07 %) as compared to 2021 (0.97 %). The interaction between year and treatment (Y×T) showed highest (1.34 %) oil percentage under Y_2T_8 whereas lowest (0.72 %) under Y_1T_{10}. The composite effect of year and treatment (Y×C) recorded; minimum oil percentage under Y_1C_1 (0.96 %) and maximum under Y_2C_2 (1.10 %). Lastly interaction between year, treatment and planting condition (Y×T×C) recorded maximum oil percentage in $Y_2T_8C_2$ (1.37 %) and minimum in $Y_1T_{10}C_1$ (0.73 %).

The results substantiate the previous findings of the Shahi *et al*. (2012) and Abdou *et al.* (2014), they reported that oil content of *lemongrass* positively responded to the application of different nutrient sources as compared to the control. The essential oil production in second year was more than the first year. The results are in line with the findings of El-Sayed *et al*. (2018).

4.1.8 Oil yield (kg ha^{-1})

It is evident from the data presented in Table 9 that year, treatment and planting condition had significant effect on oil yield. Whereas, interaction effect between year and treatment (Y×T) as well as cumulative effect of year, treatment and planting condition (Y×T×C), did not display any significant effect on oil yield. During the year 2021, among different treatments minimum oil yield was observed in T_{10} (27.59 kg ha^{-1}) and maximum in T_8 (77.57 kg ha^{-1}). Counting to the different planting condition lowest oil yield was observed in C_1 (49.86 kg ha^{-1}) followed by C_2 (55.84 kg ha^{-1}). Cumulative effect of treatment and planting condition (T×C) recorded minimum oil yield in $T_{10}C_1$ (25.66 kg ha^{-1}) and maximum in T_8C_2 (81.28 kg ha^{-1}).

During the year 2022, treatment effect revealed that lowest oil yield was recorded under treatment T_{10} (44.50 kg ha^{-1}) whereas highest oil yield was recorded under T_8 (133.57 kg ha^{-1}). Under different planting condition; lower oil yield was recorded in C_1 (88.77 kg ha^{-1}) compared to C_2 (97.68 kg ha^{-1}). Interaction between the treatment and planting condition (T×C) showed that treatment combination $T_{10}C_1$ (41.86 kg ha^{-1}) was having lowest oil yield while highest oil yield was found in T_8C_2 (138.65 kg ha^{-1}).

Pooled data of both the years revealed that among different treatments, T_{10} (36.05 kg ha^{-1}) recorded minimum and T_8 (105.57 kg ha^{-1}) maximum oil yield. Under different planting condition, open condition showed higher (76.76 kg ha^{-1}) oil yield when compared to agroforestry system (69.31 kg ha^{-1}). Cumulative effect of treatment and condition (T×C) depicts that treatment combination $T_{10}C_1$ (33.76 kg ha^{-1}) recorded minimum oil yield and maximum oil yield was recorded in T_8C_2 (109.96 kg ha^{-1}). In general, oil yield was low in the 2021 (52.85 kg ha^{-1}) than the year 2022 (93.22 kg ha^{-1}). Considering the interaction effect of year and planting condition (Y×C) revealed that oil yield was lowest in Y_1C_1 (49.86 kg ha^{-1}) whereas highest under Y_2C_2 (97.68 kg ha^{-1}).

The current findings could be explained by nitrogen role in encouraging vegetative development, that enhanced herbage output which in turn increased essential oil yield to a greater extent. In addition to releasing the nutrient elements to the soil, organic manures have also been shown to improve other soil physico-chemical properties, which further enhanced crop growth and development (Ahmad *et al*., 2011, Akintola *et al*., 2021). Another possible explanation for this could be the balanced nutrition which might result in

Table 9: Effect of organic manures and planting conditions on oil yield (kg/ha) of lemongrass

Treatments / Conditions	2021 (Y_1)			2022 (Y_2)			Pooled		
	Agroforestry system (C_1)	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**
T_1	40.18	44.96	**42.57**	70.64	79.95	**75.30**	55.41	62.46	**58.93**
T_2	43.57	47.89	**45.73**	78.74	88.87	**83.80**	61.15	68.38	**64.77**
T_3	49.31	55.26	**52.29**	88.68	97.42	**93.05**	69.00	76.34	**72.67**
T_4	55.20	62.63	**58.91**	98.45	108.80	**103.62**	76.82	85.71	**81.27**
T_5	34.10	40.20	**37.15**	65.78	74.13	**69.95**	49.94	57.16	**53.55**
T_6	58.23	63.44	**60.83**	103.81	113.45	**108.63**	81.02	88.44	**84.73**
T_7	66.53	74.03	**70.28**	116.96	126.01	**121.48**	91.74	100.02	**95.88**
T_8	73.87	81.28	**77.57**	128.50	138.65	**133.57**	101.18	109.96	**105.57**
T_9	51.93	59.17	**55.55**	94.24	102.38	**98.31**	73.08	80.77	**76.93**
T_{10}	25.66	29.52	**27.59**	41.86	47.14	**44.50**	33.76	38.33	**36.05**
Mean	**49.86**	**55.84**	**52.85**	**88.77**	**97.68**	**93.22**	**69.31**	**76.76**	
$CD_{0.05}$									
Year	1.32								
Treatment	2.95								
Condition	1.32								
Year × Treatment	Non-significant								
Year × Condition	1.86								
Treatment × Condition	4.17								
Year × Treatment × Condition	Non-significant								

T_1: Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis), **T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis, **T_8**: Goat manure and RDN on 50:50 equivalence basis, **T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

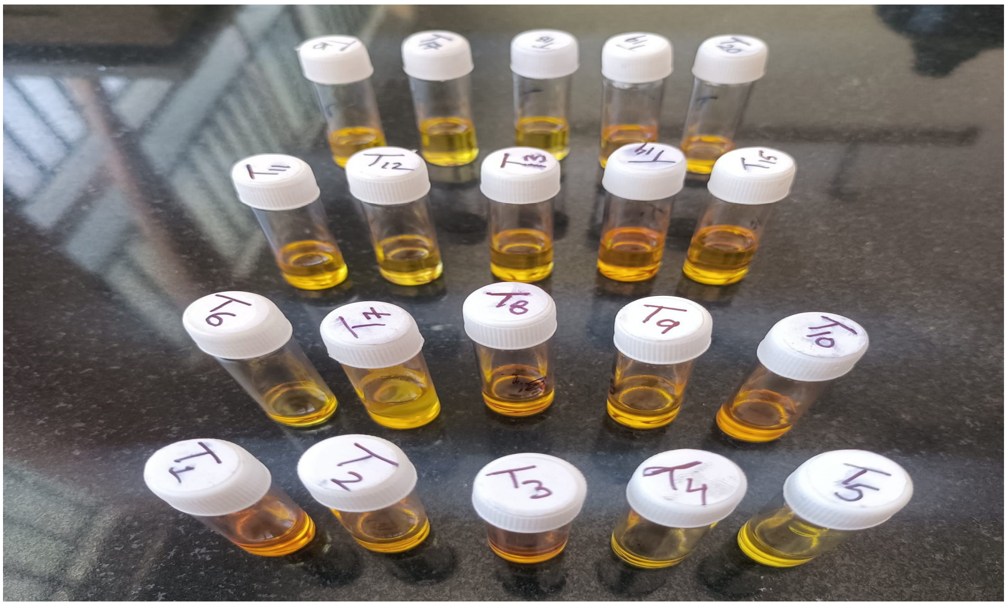


Plate 5: Lemongrass essential oil

accelerating the photosynthetic activities and improved sink (Kumar *et al*., 2015). Also, the reduced bulk density due to organic manure application implies better aeration besides good soil physical condition that would help in root penetration and proliferation essential for vigorous growth and high yield of the crop (Ganiger *et al*., 2012). Similar results were reported by Gonmie *et al*. (2018) and Priyadharshini *et al*. (2021). The increase in the overall yield could be due to the addition of organic sources of nutrients which increases the effectiveness of using nitrogen, aids in phosphorus solubilization and absorption, increases potassium availability and recovers micro and macronutrients, all of which contribute to improved growth and production (Mahmood *et al*., 2017).

4.1.9 Acid value (mg KOH/g)

4.1.9.1 Fresh leaves oil acid value (mg KOH/g)

The acid value is the weight of potassium hydroxide in mg required to neutralize the organic acids present in 1 g of the substance (Olayemi *et al*., 2018). The acid value is an index which helps to identify any rancidity, to estimate the oxidation and to specify the quality of oil. The low acid value of oil makes it less exposed to rancidity (Benoudjit *et al*., 2022). The conjecture data presented in Table 10 revealed that year, treatment and planting condition had significant effect on acid value, however their interaction induced no significant effect on acid value.

During the year 2021, among different treatments minimum acid value was observed in T_8 (4.21 mg KOH/g) and maximum in T_{10} (4.42 mg KOH/g). Counting to the different planting condition lower acid value was observed in C_2 (4.29 mg KOH/g) followed by C_1 (4.32 mg KOH/g). During the year 2022, treatment effect revealed that lowest acid value was recorded under treatment T_8 (4.17 mg KOH/g) whereas highest acid value was recorded under T_{10} (4.38 mg KOH/g). Under different planting condition; minimum acid value was recorded in C_2 (4.25 mg KOH/g) and maximum acid value was recorded in C_1 (4.29 mg KOH/g).

Pooled data of both the years revealed that among different treatments, T_8 (4.19 mg KOH/g) recorded minimum and T_{10} (4.40 mg KOH/g) maximum acid value. Under different planting condition, open condition showed lower (4.27 mg KOH/g) acid value when compared to agroforestry system (4.31 mg KOH/g).

Table 10: Effect of organic manures and planting conditions on fresh leaves oil acid value (mg KOH/g) of lemongrass

Treatments / Conditions	2021 (Y_1)			2022 (Y_2)			Pooled		
	Agroforestry system (C_1)	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**
T_1	4.42	4.39	**4.40**	4.38	4.34	**4.36**	4.40	4.36	**4.38**
T_2	4.33	4.30	**4.31**	4.30	4.25	**4.27**	4.31	4.27	**4.29**
T_3	4.31	4.28	**4.30**	4.28	4.24	**4.26**	4.30	4.26	**4.28**
T_4	4.29	4.27	**4.28**	4.26	4.21	**4.23**	4.27	4.24	**4.26**
T_5	4.39	4.36	**4.37**	4.36	4.31	**4.33**	4.37	4.33	**4.35**
T_6	4.28	4.25	**4.27**	4.26	4.21	**4.24**	4.27	4.23	**4.25**
T_7	4.25	4.22	**4.24**	4.22	4.18	**4.20**	4.24	4.20	**4.22**
T_8	4.22	4.19	**4.21**	4.19	4.15	**4.17**	4.21	4.17	**4.19**
T_9	4.29	4.26	**4.28**	4.26	4.22	**4.24**	4.28	4.24	**4.26**
T_{10}	4.43	4.42	**4.42**	4.41	4.35	**4.38**	4.42	4.38	**4.40**
Mean	**4.32**	**4.29**	**4.31**	**4.29**	**4.25**	**4.27**	**4.31**	**4.27**	
$CD_{0.05}$									
Year	0.01								
Treatment	0.01								
Condition	0.01								
Year × Treatment	Non-significant								
Year × Condition	Non-significant								
Treatment × Condition	Non-significant								
Year × Treatment × Condition	Non-significant								

T_1: Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis), **T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis, **T_8**: Goat manure and RDN on 50:50 equivalence basis, **T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

Plate 6: Quality analysis of lemongrass essential oil in lab

4.1.9.2 Dry leaves oil acid value (mg KOH/g)

The inferences drawn from the Table 11 showed that year, treatment and planting condition had significant effect on dry leaves oil acid value of essential oil. However, the cumulative effect of interaction between treatment and planting condition (T×C) as well as year, treatment and planting condition (Y×T×C) induced no significant effect on acid value.

In year 2021, among planting condition maximum acid value was recorded in C_1 (4.50 mg KOH/g) and minimum acid value was recorded in C_2 (4.47 mg KOH/g). Among different treatments highest acid value was observed in treatment T_{10} (4.60 mg KOH/g) whereas acid value was lowest in T_8 (4.39 mg KOH/g).

In the year 2022 same trends were noticed where higher acid value was recorded in C_1 (4.48 mg KOH/g) while lower acid value was recorded in C_2 (4.44 mg KOH/g). The treatment effect revealed that maximum acid value was recorded under treatment T_{10} (4.57 mg KOH/g) whereas, minimum acid value was recorded under T_8 (4.36 mg KOH/g).

Pooled data of both the years showed that among different planting condition, agroforestry system (4.49 mg KOH/g) outperformed in acid value when compared to open condition (4.46). Under different treatments, T_{10} (4.59 mg KOH/g) recorded highest acid value and T_8 (4.37 mg KOH/g) recorded lowest acid value.

Further it has been noticed that higher acid value was recorded in year 2021 (4.49 mg KOH/g) as compared to year 2022 (4.46 mg KOH/g). Interaction between year and planting condition (Y×C) had significant effect on acid value; depicting maximum acid value was recorded in Y_1C_1 (4.50 mg KOH/g) and minimum acid value was recorded in Y_2C_2 (4.44 mg KOH/g). Composite effect of year and treatment (Y×T) showed highest acid value under Y_1T_{10} (4.60 mg KOH/g) whereas lowest under Y_2T_8 (4.36 mg KOH/g).

The results indicated that in case of essential oil extracted from both fresh leaves and dry leaves, integrated nutrient management where organic manures were applied along with the inorganic fertilizers, recorded lower acidic values. The results are in conformity with the findings of Gayathri and Krishnaveni (2015), they observed that the quality parameters increase significantly by the application of different organic manures with nitrogenous fertilizers compared to the control and complete inorganic fertilizers. The acid value obtained varied between 4.15 mg KOH/g to 4.43 mg KOH/g in essential oil extracted from fresh leaves and 4.35 mg KOH/g to 4.61 mg KOH/g in essential oil extracted from dry leaves.

Table 11: Effect of organic manures and planting conditions on dry leaves oil acid value (mg KOH/g) of lemongrass

Treatments / Conditions	2021 (Y_1)			2022 (Y_2)			Pooled		
	Agroforestry system (C_1)	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**
T_1	4.60	4.57	**4.58**	4.57	4.54	**4.55**	4.58	4.55	**4.57**
T_2	4.51	4.48	**4.49**	4.48	4.45	**4.46**	4.49	4.46	**4.48**
T_3	4.49	4.46	**4.48**	4.47	4.44	**4.45**	4.48	4.45	**4.46**
T_4	4.47	4.45	**4.46**	4.44	4.41	**4.42**	4.46	4.43	**4.44**
T_5	4.57	4.54	**4.55**	4.54	4.51	**4.52**	4.55	4.52	**4.54**
T_6	4.46	4.43	**4.45**	4.44	4.41	**4.43**	4.45	4.42	**4.44**
T_7	4.43	4.40	**4.42**	4.41	4.38	**4.39**	4.42	4.39	**4.40**
T_8	4.40	4.37	**4.39**	4.38	4.35	**4.36**	4.39	4.36	**4.37**
T_9	4.47	4.44	**4.46**	4.45	4.42	**4.43**	4.46	4.43	**4.44**
T_{10}	4.61	4.60	**4.60**	4.58	4.56	**4.57**	4.60	4.58	**4.59**
Mean	**4.50**	**4.47**	**4.49**	**4.48**	**4.44**	**4.46**	**4.49**	**4.46**	
$CD_{0.05}$									
Year	0.01								
Treatment	0.01								
Condition	0.01								
Year × Treatment	0.02								
Year × Condition	0.01								
Treatment × Condition	Non-significant								
Year × Treatment × Condition	Non-significant								

T_1: Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis), **T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis, **T_8**: Goat manure and RDN on 50:50 equivalence basis, **T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

Similar results were reported by Mustapha (2018) and Dutta *et al*. (2014). This value is within the specification of 30 prescribed by the FAO (2015). The acid value impacts the storage quality of oil, with a higher value indicating lower storage quality (Abera, 2020). Thus, acid values obtained in present study shows that the quality of the lemongrass oil extract will not deteriorate significantly upon storage. Since the acid value is lower than the 10 acceptable limits for edible oil, the lemongrass oil extract can be used in food manufacturing industries as an additive (Mahendran and Kumar, 1997, Sampson, 2005).

4.1.10 Saponification value (mg KOH/g)

4.1.10.1 Fresh leaves oil saponification value (mg KOH/g)

Data demonstrated in Table 12 showed that year, treatment, planting condition and their interactions had significant effect on saponification value. During the year 2021, among different treatments minimum saponification value was observed in T_{10} (139.48 mg KOH/g) and maximum in T_8 (146.17 mg KOH/g). Counting to the different planting condition lowest saponification value was observed in C_1 (143.81 mg KOH/g) followed by C_2 (143.66 mg KOH/g). Cumulative effect of treatment and planting condition (T×C) recorded minimum saponification value in $T_{10}C_1$ (139.37 mg KOH/g) and maximum in T_8C_2 (146.33 mg KOH/g).

During the year 2022, treatment effect revealed that lowest saponification value was recorded under treatment T_{10} (139.95 mg KOH/g) whereas highest saponification value was recorded under T_8 (146.59 mg KOH/g). Under different planting condition; lower saponification value was recorded in C_1 (143.95 mg KOH/g) than C_2 (144.36 mg KOH/g). Interaction between the treatment and planting condition (T×C) showed that treatment combination $T_{10}C_1$ (139.66 mg KOH/g) was having lowest saponification value while highest saponification value was found in T_8C_2 (146.87 mg KOH/g).

Pooled data of both the years revealed that among different treatments, T_{10} (139.71 mg KOH/g) recorded minimum and T_8 (146.38 mg KOH/g) maximum saponification value. Under different planting condition, open condition showed higher (144.08 mg KOH/g) saponification value when compared to agroforestry system (143.80 mg KOH/g). Cumulative effect of treatment and condition (T×C) depicts that treatment combination $T_{10}C_2$ (139.52 mg KOH/g) recorded minimum saponification value and maximum saponification value was recorded in T_8C_1 (146.60 mg KOH/g).

Table 12: Effect of organic manures and planting conditions on fresh leaves oil saponification value (mg KOH/g) of lemongrass

Conditions / Treatments	2021 (Y_1)			2022 (Y_2)			Pooled		
	Agroforestry system (C_1)	Open (C_2)	Mean	Agroforestry system (C_1)	Open (C_2)	Mean	Agroforestry system (C_1)	Open (C_2)	Mean
T_1	141.28	141.53	**141.41**	141.57	142.02	**141.80**	141.43	141.78	**141.60**
T_2	143.38	143.51	**143.44**	143.64	144.04	**143.84**	143.51	143.78	**143.64**
T_3	143.55	143.67	**143.61**	144.23	144.22	**144.22**	143.89	143.94	**143.92**
T_4	144.32	144.61	**144.47**	144.26	145.13	**144.70**	144.29	144.87	**144.58**
T_5	143.46	143.11	**143.28**	143.73	143.83	**143.78**	143.59	143.47	**143.53**
T_6	145.40	145.62	**145.51**	145.69	146.13	**145.91**	145.54	145.87	**145.71**
T_7	145.93	146.04	**145.99**	146.22	146.56	**146.39**	146.07	146.30	**146.19**
T_8	146.01	146.33	**146.17**	146.30	146.87	**146.59**	146.15	146.60	**146.38**
T_9	143.87	144.06	**143.97**	144.16	144.57	**144.37**	144.02	144.32	**144.17**
T_{10}	139.37	139.58	**139.48**	139.66	140.23	**139.95**	139.52	139.90	**139.71**
Mean	**143.66**	**143.81**	**143.73**	**143.95**	**144.36**	**144.15**	**143.80**	**144.08**	
$CD_{0.05}$									
Year	0.06								
Treatment	0.12								
Condition	0.06								
Year × Treatment	0.18								
Year × Condition	0.08								
Treatment × Condition	0.18								
Year × Treatment × Condition	0.25								

T_1: Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis), **T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis, **T_8**: Goat manure and RDN on 50:50 equivalence basis, **T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

In general, saponification value was low in the 2021 (143.73 mg KOH/g) than the year 2022 (144.15 mg KOH/g). The interaction between year and treatment (Y×T) showed highest saponification value under Y_2T_8 (146.59 mg KOH/g) whereas lowest under Y_1T_{10} (139.48 mg KOH/g). The composite effect of year and treatment (Y×C) recorded; minimum saponification value under Y_1C_1 (143.66 mg KOH/g) and maximum under Y_2C_2 (144.36 mg KOH/g). Lastly interaction between year, treatment and planting condition (Y×T×C) recorded maximum saponification value in $Y_2T_8C_2$ (146.87 mg KOH/g) and minimum in $Y_1T_{10}C_1$ (139.37 mg KOH/g).

4.1.10.2 Dry leaves oil saponification value (mg KOH/g)

Data demonstrated in Table 13 showed that year, treatment, planting condition and their interactions had significant effect on dry leaves oil saponification value, except interaction between treatment and planting condition (T×C). Pertaining to the year 2021, among different planting condition highest saponification value was recorded in C_2 (142.55 mg KOH/g) and lowest was recorded in C_1 (142.41 mg KOH/g). Among different manure treatments maximum saponification value was observed in treatment T_8 (144.96 mg KOH/g) whereas saponification value was minimum in T_{10} (138.20 mg KOH/g).

In the year 2022, among planting condition higher saponification value was recorded in C_2 (143.09 mg KOH/g) as compared to C_1 (142.74 mg KOH/g). Treatment, effect revealed that maximum saponification value was recorded under treatment T_8 (145.40 mg KOH/g) whereas minimum saponification value was recorded under T_{10} (138.65 mg KOH/g).

Pooled data of both the years showed that among different planting condition, open condition (142.82 mg KOH/g) recorded higher saponification value when compared to agroforestry system (142.58 mg KOH/g). Under different treatments, T_8 (145.18 mg KOH/g) recorded highest saponification value and T_{10} (138.42 mg KOH/g) lowest saponification value.

Further it has been noticed that saponification value was higher in year 2022 (142.92 mg KOH/g) as compared to year 2021 (142.48 mg KOH/g). The interaction between year and treatment (Y×T) showed highest saponification value under Y_2T_8 (145.40 mg KOH/g) whereas lowest under Y_1T_{10} (138.20 mg KOH/g). The composite effect of year and treatment

Table 13: Effect of organic manures and planting conditions on dry leaves oil saponification value (mg KOH/g) of lemongrass

Conditions / Treatments	2021 (Y_1)			2022 (Y_2)			Pooled		
	Agroforestry system (C_1)	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**
T_1	140.04	140.29	**140.16**	140.36	140.75	**140.56**	140.20	140.52	**140.36**
T_2	142.13	142.18	**142.15**	142.47	142.73	**142.60**	142.30	142.45	**142.38**
T_3	142.31	142.43	**142.37**	143.07	142.97	**143.02**	142.69	142.70	**142.69**
T_4	143.08	143.36	**143.22**	143.07	143.92	**143.50**	143.08	143.64	**143.36**
T_5	142.21	141.85	**142.03**	142.47	142.53	**142.50**	142.34	142.19	**142.26**
T_6	144.16	144.33	**144.24**	144.49	144.84	**144.67**	144.32	144.59	**144.45**
T_7	144.68	144.80	**144.74**	145.02	145.26	**145.14**	144.85	145.03	**144.94**
T_8	144.77	145.16	**144.96**	145.10	145.70	**145.40**	144.93	145.43	**145.18**
T_9	142.63	142.82	**142.73**	142.97	143.32	**143.15**	142.80	143.07	**142.94**
T_{10}	138.13	138.27	**138.20**	138.36	138.94	**138.65**	138.24	138.60	**138.42**
Mean	**142.41**	**142.55**	**142.48**	**142.74**	**143.09**	**142.92**	**142.58**	**142.82**	
$CD_{0.05}$									
Year	0.10								
Treatment	0.22								
Condition	0.10								
Year × Treatment	0.31								
Year × Condition	0.14								
Treatment × Condition	Non-significant								
Year × Treatment × Condition	0.44								

T_1: Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis), **T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis, **T_8**: Goat manure and RDN on 50:50 equivalence basis, **T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

(Y×C) recorded; minimum saponification value under Y_1C_1 (142.41mg KOH/g) and maximum under Y_2C_2 (143.09 mg KOH/g). Lastly interaction between year, treatment and planting condition (Y×T×C) recorded maximum saponification value in $Y_2T_8C_2$ (145.70 mg KOH/g) and minimum in $Y_1T_{10}C_1$ (138.13 mg KOH/g).

The saponification number is a measure of the average molecular weight of the triacylglycerol's in a sample. The smaller the saponification number the larger the average molecular weight of the triacylglycerol's present i.e., saponification value is inversely proportional to the mean molecular weight of fatty acids or chain length (Olayemi *et al*., 2018). In the present study the saponification value obtained varied between 139.37 mg KOH/g to 146.87 mg KOH/g in essential oil extracted from fresh leaves and 138.13 mg KOH/g to 145.70 mg KOH/g in essential oil extracted from dry leaves. The results of the findings are in consonance with Dutta *et al*. (2014) and Abera (2020). Higher saponification justifies the enrichment of fat or oil content and can be used for cosmetics industries (Haque, 2018). Maximum saponification value was reported where integration of organic manures was done with inorganic fertilizers. These results corroborate the findings of Gayathri and Krishnaveni (2015) and Kumar *et al.* (2016), which showed superiority of integrated nutrient management in improving quality parameters over sole application of organic manures or inorganic fertilizers.

4.1.11 Fresh leaves oil iodine value (gI_2/100g)

A critical look at the data presented in Table 14 accentuates that year, treatment, planting condition and their interactions laid significant influence on iodine value of essential oil. Pertaining to the year 2021, among different planting conditions, maximum iodine value was recorded in C_2 (116.67 gI_2/100g) while minimum in C_1 (116.08 gI_2/100g), however among different doses of manures it was highest in T_8 (118.70 gI_2/100g) whereas lowest in T_{10} (112.52 gI_2/100g). Meanwhile considering the interaction effect between the treatment and planting condition (T×C), maximum iodine value was recorded in treatment combination T_8C_2 (119.04 gI_2/100g) and minimum in $T_{10}C_1$ (112.25 gI_2/100g).

In the data recorded for the year 2022 same trends were observed, where among different planting conditions highest iodine value was recorded in C_2 (117.31 gI_2/100g) and lowest in C_1 (116.70 gI_2/100g). Consequently, treatment effect revealed that maximum iodine value was recorded under T_8 (119.37 gI_2/100g) and minimum under T_{10} (113.16 gI_2/100g), however combined effect of treatment and planting condition (T×C) portrayed that treatment combination T_8C_2 (119.76 gI_2/100g) was having highest while $T_{10}C_1$ (112.87 gI_2/100g) recorded the lowest iodine value, respectively.

Pooled data of both the years showed that among different planting condition, open condition (116.99 gI_2/100g) showed higher iodine value compared to agroforestry system (116.39 gI_2/100g). Similarly, under different treatments, T_8 (119.04 gI_2/100g) recorded maximum iodine value and T_{10} (112.84 gI_2/100g) recorded the minimum iodine value. Cumulative effect of treatment and condition (T×C) depicted that treatment combination T_8C_2 (119.40 gI_2/100g) recorded highest iodine value and $T_{10}C_1$ (112.56 gI_2/100g) recorded the lowest iodine value.

Further it has been noticed that highest iodine value was recorded in year 2022 (117.00 gI_2/100g) as compared to 2021 (116.38 gI_2/100g). The interaction between year and treatment (Y×T) showed maximum iodine value under Y_2T_8 (119.37 gI_2/100g) whereas minimum under Y_1T_{10} (112.52 gI_2/100g). The composite effect of year and treatment (Y×C) recorded; lowest iodine value under Y_1C_1 (116.08 gI_2/100g) while highest under Y_2C_2 (117.31 gI_2/100g). Lastly interaction between year, treatment and planting condition (Y×T×C) recorded maximum iodine value in $Y_2T_8C_2$ (119.76 gI_2/100g) and minimum in $Y_1T_{10}C_1$ (112.25 gI_2/100g).

4.1.12 Dry leaves oil iodine value (gI_2/100g)

The data of the dry leaves oil iodine value as influenced by imposition of year, treatments and planting conditions are presented in the Table 15. It indicates significant effect of year, treatments, planting conditions and their interaction on iodine value of oil, except composite effect of year and planting condition (Y×C). During the year 2021, among different planting conditions, higher iodine value was recorded in C_2 (115.73 gI_2/100g) than C_1 (115.14 gI_2/100g), however among different doses of manures it was highest in T_8 (117.76 gI_2/100g) whereas lowest in T_{10} (111.85 gI_2/100g). Meanwhile considering the interaction effect between the treatment and planting condition (T×C), maximum iodine value was recorded in treatment combination T_8C_2 (118.11 gI_2/100g) and minimum in $T_{10}C_1$ (111.31 gI_2/100g).

Table 14: Effect of organic manures and planting conditions on fresh leaves oil iodine value (gI_2/100g) of lemongrass

Treatments / Conditions	2021 (Y_1)			2022 (Y_2)			Pooled		
	Agroforestry system (C_1)	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**
T_1	114.26	114.91	**114.58**	114.88	115.55	**115.21**	114.57	115.23	**114.90**
T_2	115.94	116.23	**116.08**	116.56	116.83	**116.69**	116.25	116.53	**116.39**
T_3	115.97	116.74	**116.35**	116.59	117.36	**116.97**	116.28	117.05	**116.66**
T_4	116.64	117.32	**116.98**	117.26	117.96	**117.61**	116.95	117.64	**117.30**
T_5	114.76	115.35	**115.06**	115.38	115.96	**115.67**	115.07	115.66	**115.36**
T_6	117.67	118.18	**117.92**	118.29	118.80	**118.54**	117.98	118.49	**118.23**
T_7	118.01	118.65	**118.33**	118.63	119.27	**118.95**	118.32	118.96	**118.64**
T_8	118.36	119.04	**118.70**	118.98	119.76	**119.37**	118.67	119.40	**119.04**
T_9	116.94	117.52	**117.23**	117.56	118.12	**117.84**	117.25	117.82	**117.53**
T_{10}	112.25	112.79	**112.52**	112.87	113.44	**113.16**	112.56	113.12	**112.84**
Mean	**116.08**	**116.67**	**116.38**	**116.70**	**117.31**	**117.00**	**116.39**	**116.99**	
$CD_{0.05}$									
Year	0.04								
Treatment	0.08								
Condition	0.04								
Year × Treatment	0.11								
Year × Condition	0.05								
Treatment × Condition	0.11								
Year × Treatment × Condition	0.16								

T_1: Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis), **T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis, **T_8**: Goat manure and RDN on 50:50 equivalence basis, **T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

Table 15: Effect of organic manures and planting conditions on dry leaves oil iodine value (gI_2/100g) of lemongrass

Treatments / Conditions	2021 (Y_1)			2022 (Y_2)			Pooled		
	Agroforestry system (C_1)	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**
T_1	113.32	113.98	**113.65**	113.93	114.60	**114.26**	113.62	114.29	**113.95**
T_2	115.00	115.29	**115.15**	115.61	115.91	**115.76**	115.30	115.60	**115.45**
T_3	115.03	115.80	**115.41**	115.64	116.42	**116.03**	115.33	116.11	**115.72**
T_4	115.70	116.39	**116.04**	116.31	117.01	**116.66**	116.00	116.70	**116.35**
T_5	113.82	114.42	**114.12**	114.43	115.04	**114.73**	114.12	114.73	**114.42**
T_6	116.73	117.24	**116.98**	117.34	117.87	**117.61**	117.03	117.56	**117.29**
T_7	117.07	117.71	**117.39**	117.68	118.33	**118.01**	117.37	118.02	**117.70**
T_8	117.42	118.11	**117.76**	118.03	118.74	**118.39**	117.72	118.42	**118.07**
T_9	116.00	116.58	**116.29**	116.61	117.20	**116.90**	116.30	116.89	**116.59**
T_{10}	111.31	111.85	**111.58**	111.92	112.47	**112.20**	111.61	112.16	**111.89**
Mean	**115.14**	**115.73**	**115.44**	**115.75**	**116.36**	**116.05**	**115.44**	**116.05**	
$CD_{0.05}$									
Year	0.02								
Treatment	0.04								
Condition	0.02								
Year × Treatment	0.05								
Year × Condition	Non-significant								
Treatment × Condition	0.05								
Year × Treatment × Condition	0.07								

T_1: Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis), **T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis, **T_8**: Goat manure and RDN on 50:50 equivalence basis, **T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

In the data recorded for the year 2022 same trends were observed, where among two planting conditions; highest iodine value was recorded in C_2 (116.36 gI_2/100g) and lowest in C_1 (115.75 gI_2/100g). Consequently, treatment effect revealed that maximum iodine value was recorded under T_8 (118.39 gI_2/100g) and minimum under T_{10} (112.20 gI_2/100g), however combined effect of treatment and planting condition (T×C) portrayed that treatment combination T_8C_2 (118.74 gI_2/100g) was having highest while $T_{10}C_1$ (111.92 gI_2/100g) recorded the lowest iodine value, respectively.

Pooled data of both the years showed that among different planting condition, open condition (116.05 gI_2/100g) showed more iodine value when compared to agroforestry system (115.44 gI_2/100g). Similarly, under different treatments, T_8 (118.07 gI_2/100g) recorded highest iodine value and T_{10} (111.89 gI_2/100g) recorded the lowest. Cumulative effect of treatment and condition (T×C) depicted that treatment combination T_8C_2 recorded maximum (118.42 gI_2/100g) iodine value and $T_{10}C_1$ recorded the minimum (111.61 gI_2/100g).

Further it has been noticed that higher iodine value was recorded in year 2022 (116.05 gI_2/100g) as compared to 2021 (115.44 gI_2/100g). The composite effect of year and treatment (Y×T) recorded; minimum iodine value in year 2021 under Y_1T_{10} (111.58 gI_2/100g) and maximum in year 2022 under Y_2T_8 (118.39 gI_2/100g).

The iodine value obtained ranged between 112.25 mg/100g to 119.76 mg/100g, of the oil extracted from fresh leaves and 111.31 mg/100g to 118.74 mg/100g, of the oil extracted from dry leaves. The value obtained was within the range of established standard 104-120 (Codex standard, 2001). These values fall within the prescribed range of semi-drying of oil i.e., 100-300 mg/100g (Kagwachie and Anozie, 1995, Ifeanyichukwu and Onoriode, 2023). The observations are in agreement with the findings of Dutta *et al*. (2014) and Muazu *et al*. (2019). The iodine value gives an idea of the average degree of unsaturation in oil and its stability to oxidation. Higher the iodine value, greater the number double bonds in the sample and therefore greater care will be needed to slow down oxidation (Meftahizade *et al*., 2010). In contrast, low iodine value may be indicative of low susceptibility to oxidative rancidity (Obasi *et al*., 2012). Iodine value is directly proportional to the degree of unsaturation (number of double bonds) and inversely proportional to the melting point of lipid. This value could be used to quantify the amount of double bonds present in the oil, which signifies the susceptibility of oil to oxidation (Olayemi *et al*., 2018). The present study also revealed that combined application of organic manures with inorganic fertiliser sources resulted highest iodine value when compared to sole application of organic manure or inorganic fertilizers. The results are in consistent with the findings of Gayathri and Krishnaveni (2015) and Sachan *et al*. (2017). This might be because, the organic sources besides supplying N, P and K also make unavailable sources of elemental nitrogen, bound phosphates, micronutrients, and decomposed plant residues into an available form to facilitate to plant to absorb the nutrients. Kumar and Chopra (2011) and Kumar (2016).

4.1.13 Essential oil compound/components

Twenty components were identified in the fresh and dried leaves essential oil of lemongrass. The chemical constituents of oils are presented in Table 16. Different compounds found in lemongrass oil were, Geranial (Citral a), Neral (Citral b), 2-Isopropenyl-5-methylhex-4-enal, 4,8 Dimethyl-nona-3,8-dien-2-one, Geranyl acetate/Geranyl vinyl ether, 3,7-Nonadien-2-one, 4,8-dimethyl-, Myrcene, Neric acid, Diethylmalonic acid, di(5-methoxy-3-methylpentyl) ester, Tetrapentacontane, 1,54-dibromo-,17- Pentatriacontene, Oleic acid, 3- (octadecyloxy) propyl ester, Oleic acid, eicosyl ester, 1,3-Dioxolane, 2-(6-octenyl)-, (Z)-, Isopropyl, Octanal, 7-methoxy-3,7-dimethyl-,2-methyl-2-(4-methyl-3-pentenyl)-, 2-Pentanone, 4-hydroxy-4-methyl- and others. The study revealed that Geranial (Citral-a) and Neral (Citral-b) were major compounds found in lemongrass essential oil. Citral a and Citral b, content was recorded highest in treatment T_8 (50 % goat manure + 50 % RDN), 48.54 % and 33.61 % in open condition while 47.64 % and 28.77 %, respectively under wild pomegranate-based agroforestry system. Lowest Citral a and Citral b content was recorded in T_{10} (control), 17.93 % and 14.03 % in open condition and 17.27 % and 11.44 %, respectively under agroforestry system. These results are in conformity with the findings of Gayathri and Krishnaveni (2015) and Kumar (2016), Sachan *et al*. (2017) and Altaf *et al*. (2019), which showed superiority of integrated nutrient management in improving quality parameters of crops, over sole application of organic manures or inorganic fertilizers. The results corroborate the findings of Nour *et al.* (2013), Dutta *et al.* (2014), Ranitha *et al.* (2014), Olayemi *et al.* (2018) and Benoudjit *et al.* (2022) who reported Citral a and Citral b as major components of lemongrass essential oil. The results are also in line with the findings of Ali *et al.* (2017), Wagh *et al.* (2021) and El-Kased and El-Kersh (2021). Citral a and Citral b, play a significant role in determining aroma, flavour and potential therapeutic properties of

Table 16: Effect of organic manures and planting conditions on compound/components of lemongrass essential oil (%)

Sr no.	Compounds	Treatments																			
		T1		T2		T3		T4		T5		T6		T7		T8		T9		T10	
		AFS	Open	AFS	Open	AFS	Open	AFS	Open	AFS	Open	AFS	Open	AFS	Open	AFS	Open	AFS	Open	AFS	Open
1	Geranial (Citral A)	21.38	22.04	22.75	26.41	27.42	27.23	30.32	35.29	18.04	19.42	39.23	45.11	46.48	46.86	47.64	48.54	22.04	22.42	17.27	17.93
2	Neral (Citral B)	16.03	15.59	18.26	19.6	19.91	17.08	21.12	21.41	13.59	14.02	25.71	33.24	32.52	29.48	28.77	33.61	15.59	170	11.44	14.03
3	2-Isopropenyl-5-methylhex-4-enal	19.89	18.01	19.46	19.6	19.99	6.09	13.4	6.48	18.01	22.77	5.5	3.47	3.69	4.99	8.87	3.46	18.01	21.79	1.03	17.33
4	4,8-Dimethyl-nona-3,8-dien-2-one	25.26	22.46	26.05	26.43	23.61	4.51	17.28	-	22.46	30.73	-	8.57	7.88	-	-	7.36	22.46	30.73	-	17.51
5	Geranyl acetate/Geranyl vinyl ether	3.36	2.58	4.77	5	3.7	-	-	6.88	3.58	6.12	11.69	5.02	3.43	6.69	40	3.66	2.58	3.12	5.08	2.66
6	3,7-Nonadien-2-one, 4,8-dimethyl-	-	-	-	-	-	-	2.16	-	-	-	-	-	-	-	-	-	-	-	0.99	-
7	Myrcene	2.74	2.51	3.94	-	2.33	-	-	-	4.51	-	-	-	-	-	-	-	2.51	-	-	2.43
8	Neric acid	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.25	-	-	-	-	-
9	Diethylmalonic acid, di(5-methoxy-3-methylpentyl) ester	3.89	3.27	4.76	2.95	3.04	3.05	4.77	3.85	4.27	6.94	7.21	4.6	5.99	8.06	4.46	3.37	3.27	4.94	12.05	3.35
10	Tetrapentacontane, 1,54-dibromo-	4.75	2.46	-	-	-	12.65	2.54	8.98	3.46	-	-	-	-	-	-	-	2.46	-	1.5	5.16
11	17- Pentatriacontene	2.71	2.2	-	-	-	12.38	2.21	10.25	3.2	-	-	-	-	-	-	-	2.2	-	1.47	9.76
12	Oleic acid, 3- (octadecyloxy) propyl ester	-	2.75	-	-	-	9.84	2.52	2.95	2.75	-	-	-	-	-	-	-	2.75	-	1.62	9.84
13	Oleic acid, eicosyl ester	-	6.12	-	-	-	2.22	3.69	3.91	6.13	-	-	-	-	-	-	-	6.12	-	52.45	-
14	1,3-Dioxolane, 2-(6-octenyl)-, (Z)-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16	Isopropyl	-	-	-	-	-	-	-	-	-	-	-	-	-	3.92	-	-	-	-	-	-
17	Octanal, 7-methoxy-3,7-dimethyl-	-	-	-	-	-	-	-	-	-	-	4.3	-	-	-	-	-	-	-	-	-
18	2-methyl-2-(4-methyl-3-pentenyl)-	-	-	-	-	-	-	-	-	-	-	6.36		-	-	-	-	-		-	-
19	2-Pentanone, 4-hydroxy-4-methyl-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	Other	-	-	-	-	-	4.95	-	-	-	-	-	-	-	-	-	-	-	-	47.55	-

T_1: Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis), **T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis, **T_8**: Goat manure and RDN on 50:50 equivalence basis, **T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

the essential oil (Han *et al.,* 2017). These two compounds have various health benefits, including antimicrobial, anti-inflammatory, and antioxidant properties (Sokovic *et al.,* 2010 and Mukarram *et al.* (2022). The presence of Citral a and Citral b in lemongrass essential oil is a key factor in deciding its commercial value. Higher the percentage of these two compounds, higher will the market value and such essential oil is preferred more by high grade cosmetics, flavouring and pharmaceutical industries. Whereas, if the percentage of Citral a and Citral b is lower, than the oil is used for lower grade soaps and cosmetics preparation (Premathilake *et al.* 2018 and Do *et al.* 2021).

4.1.14 Correlation between the different parameters of lemongrass

The correlation between the different parameters of lemongrass was calculated by using R Studio (4.3.0) by using performance analytics package at ≤ 0.01 % level of significance and presented in Figure 4 and Figure 5. Results revealed that under both planting conditions *i.e*., agroforestry and open condition, there was strong positive correlation between different growth, yield and quality parameters of lemongrass *viz*., plant height, number of tillers, plant spread, fresh herb yield, dry herb yield, fresh leaves oil percentage, dry leaves oil percentage, fresh leaves oil saponification, dry leaves oil saponification, fresh leaves oil iodine value and dry leaves oil iodine value. Whereas, fresh leaves oil acid value and dry leaves oil acid value have negative correlation with all other parameters of lemongrass.

4.2 Growth parameters of wild pomegranate

The data regarding the various growth parameters of wild pomegranate is presented in Table 17 which shows that the average height (2.6 m), average collar diameter (16 cm), average number of primary branches per plant (7), average plant spread (1.8 m), average leaf litter per plant (40 g) and fruit yield (1.7 kg/tree) was recorded for the wild pomegranate trees during the trial period.

Table 17: Growth parameters of wild pomegranate recorded during the during period of experiment

Sr. No.	Parameters	Observation
1.	Plant height (m)	2.6
2.	Collar diameter (cm)	16
3.	No. of primary branches plant $^{-1}$	7
4.	Plant spread (m)	1.8
5.	Leaf litter (g)	40
6.	Fruit yield (kg/tree)	1.7

Plate 7: Flowering and fruiting of wild pomegranate

Figure 4: Correlation between the different parameters of lemongrass under agroforestry system

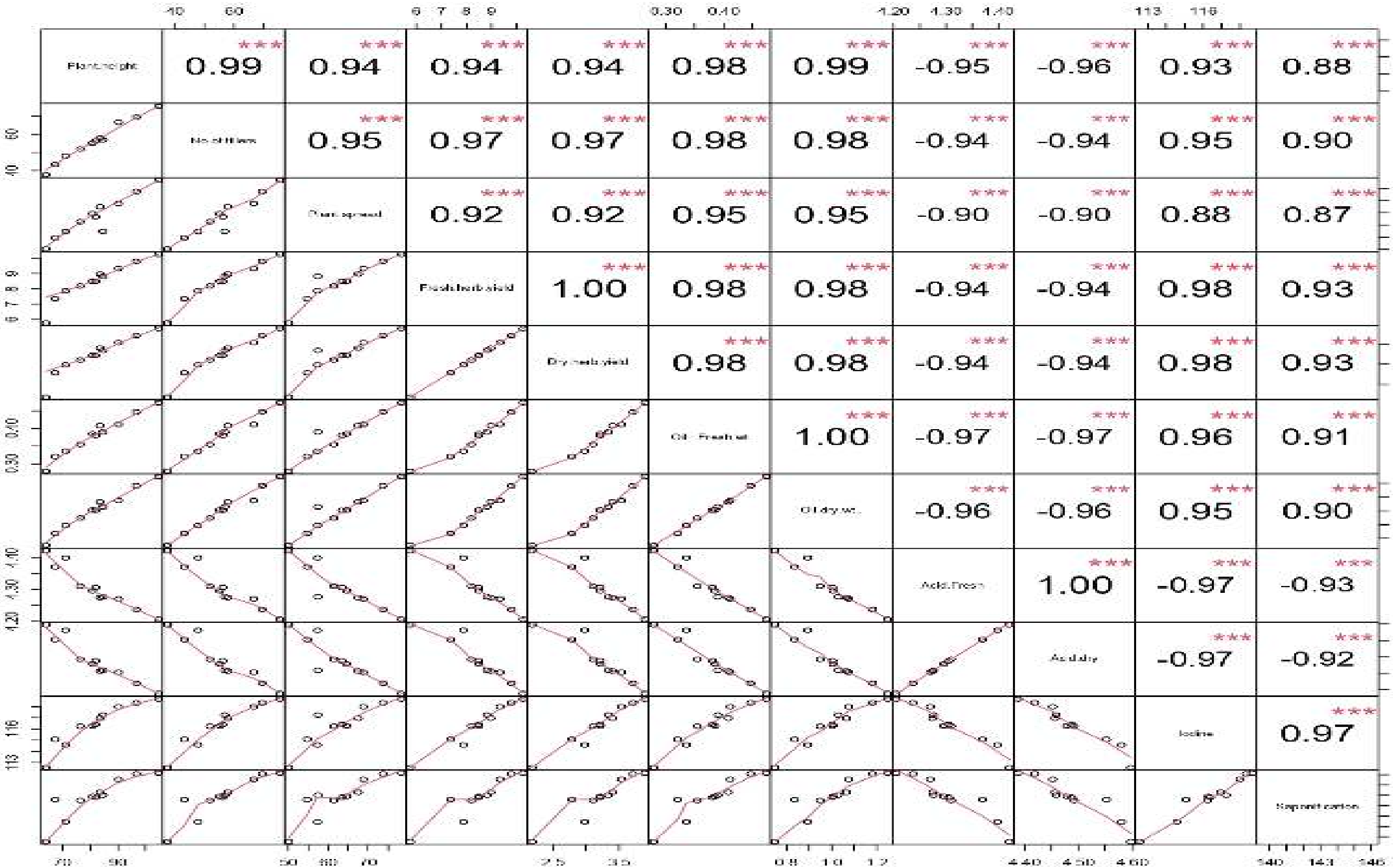
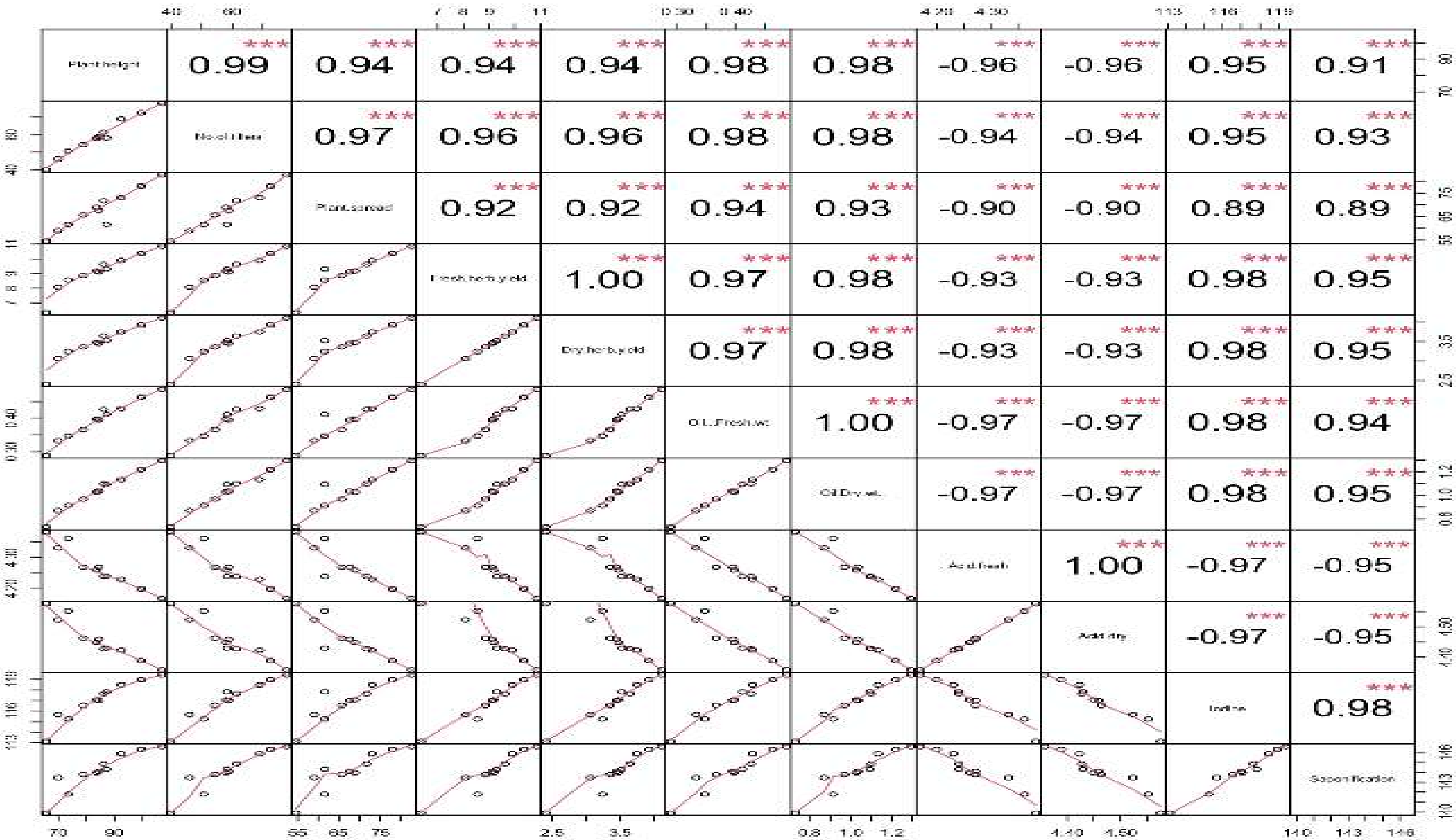


Figure 5: Correlation between the different parameters of lemongrass in open condition



4.3 TO ASSESS THE EFFECT OF ORGANIC MANURES ON SOIL PHYSICO-CHEMICAL PROPERTIES

4.3.1 Soil pH

One of the most important chemical markers of soil properties is soil pH, which depends on the source material, weathering, vegetation and climate. The pH of the soil has reportedly been impacted by ongoing applications of organic manures and inorganic fertilisers. The magnitude of the effects is determined by the type of soil, cropping systems, nutrient management techniques and the composition of the fertiliser components used. Data enumerated in Table 18 revealed that treatment, spacing, year and their interactions have significant effect on the soil pH. In year 2021, among different planting condition; higher pH was recorded in C_2 (7.02) and lower pH in C_1 (6.93). Among different treatments highest pH was observed in treatment T_{10} (7.15) whereas pH was lowest in T_4 (6.78). Under the interaction between the treatment and planting condition (T×C), maximum pH was recorded in treatment combination $T_{10}C_2$ (7.21) while minimum pH was recorded in T_4C_1 (6.70).

In the year 2022 same trends were noticed, where higher pH was recorded in C_2 (6.87) and lower pH was recorded in C_1 (6.86). The treatment effect revealed that maximum pH was recorded under treatment T_{10} (7.05) whereas minimum pH was recorded under T_4 (6.57). Combined effect of treatment and planting condition (T×C) showed that treatment combination $T_{10}C_2$ (7.09) was having highest pH while lowest pH was found in T_4C_2 (6.52).

Pooled data of both the years showed that among planting condition, open condition (6.95) indicated more pH compared to agroforestry system (6.89). Under different treatments, T_{10} (7.10) recorded highest pH while T_4 (6.67) recorded lowest pH. Cumulative effect of treatment and condition (T×C) depicts that treatment combination T_4C_1 (6.66) recorded minimum pH and maximum pH was recorded in $T_{10}C_2$ (7.15).

Further it has been noticed that highest pH was recorded in year 2021 (6.98) compared to year 2022 (6.87). Interaction between year and planting condition (Y×C) had significant on soil pH; maximum pH was recorded in Y_1C_2 (7.03) and minimum pH was recorded in Y_2C_1 (6.93). Composite effect of year and treatment (Y×T) showed highest pH under Y_1T_{10} (7.15) whereas lowest under Y_2T_4 (6.57). Interaction between year, treatment and planting condition (Y×T×C) registered significant effect on soil pH; minimum pH was recorded in $Y_2T_4C_2$ (6.52) and maximum in $Y_1T_{10}C_2$ (7.21).

Table 18: Effect of organic manures and planting conditions on soil pH

Conditions / Treatments	2021 (Y_1)			2022 (Y_2)			Pooled		
	Agroforestry system (C_1)	Open (C_2)	Mean	Agroforestry system (C_1)	Open (C_2)	Mean	Agroforestry system (C_1)	Open (C_2)	Mean
T_1	7.05	7.16	**7.11**	6.99	7.03	**7.01**	7.02	7.10	**7.06**
T_2	6.88	6.93	**6.91**	6.85	6.89	**6.87**	6.87	6.91	**6.89**
T_3	6.82	6.90	**6.86**	6.76	6.87	**6.81**	6.79	6.89	**6.84**
T_4	6.70	6.87	**6.78**	6.62	6.52	**6.57**	6.66	6.69	**6.67**
T_5	6.93	7.06	**7.00**	6.90	6.95	**6.93**	6.92	7.01	**6.96**
T_6	6.97	7.09	**7.03**	6.94	6.78	**6.86**	6.96	6.94	**6.95**
T_7	6.93	7.00	**6.96**	6.86	6.95	**6.91**	6.89	6.98	**6.93**
T_8	6.90	6.98	**6.94**	6.71	6.61	**6.66**	6.80	6.80	**6.80**
T_9	7.01	7.13	**7.07**	6.97	7.01	**6.99**	6.99	7.07	**7.03**
T_{10}	7.10	7.21	**7.15**	7.02	7.09	**7.05**	7.06	7.15	**7.10**
Mean	**6.93**	**7.03**	**6.98**	**6.86**	**6.87**	**6.87**	**6.89**	**6.95**	
$CD_{0.05}$									
Year	0.01								
Treatment	0.01								
Condition	0.01								
Year × Treatment	0.03								
Year × Condition	0.01								
Treatment × Condition	0.03								
Year × Treatment × Condition	0.04								

T_1: Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis), **T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis, **T_8**: Goat manure and RDN on 50:50 equivalence basis, **T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

The study revealed that among two planting conditions, soil pH was lower under agroforestry system as compared to control. The results are in corroboration with those of results reported by Nega and Heluf (2013) and Odunze *et al*. (2017). They reported that pH was lower under tree-based land use system compared to sole cropping system. This might be due to considerable accumulation of organic substances beneath the trees and release of weak organic acids during litter decomposition (Aguiar *et al*., 2010, Sirohi and Bangarwa, 2017).

The results also showed that addition of organic manures reduced the soil pH. The pH influences chemical solubility and availability of plant essential nutrients, pesticide performance and organic matter decomposition. Thus, it is one of the most important chemical characteristics of the soil solution because both higher plants and microorganisms respond markedly to their chemical environment. This may be attributed to the acidifying effect of organic acids produced during the course of decomposition of organic amendments (Kharadi and Bhuriya, 2020 and Yadav *et al*., 2022). The result substantiates with the previous findings of Mehraj *et al*. (2017), Mahmood *et al*. (2017) and Bhanwaria *et al*. (2022). The decrease in the soil pH with application of organic manure might be due to mineralization and later nitrification process by soil microbes present in the organic material as explicated by Ilker *et al*. (2016) and McCauley *et al*. (2017). Overall, it can be concluded that pH values in the present study ranges from 6.52 to 7.21 which is normal and requires no reclamation.

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

Data pertaining to the effect of year, treatment, planting condition and their interactions on electrical conductivity have been presented in Table 19. It could be gleaned from data that year, treatment, planting condition and their interaction have significant effect on the soil electrical conductivity during both years of study. During the year 2021, among different treatments minimum electrical conductivity was observed in T_{10} (0.226 dS m^{-1}) and maximum in T_4 (0.303 dS m^{-1}). Counting to the different planting condition lower electrical conductivity was observed in C_2 (0.222 dS m^{-1}) followed by C_1 (0.290 dS m^{-1}). Cumulative effect of treatment and planting condition (T×C) recorded minimum electrical conductivity in $T_{10}C_2$ (0.190 dS m^{-1}) and maximum in T_4C_1 (0.337 dS m^{-1}).

Table 19: Effect of organic manures and planting conditions on soil EC (dSm^{-1})

Treatments / Conditions	2021 (Y_1)			2022 (Y_2)			Pooled		
	Agroforestry system (C_1)	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**
T_1	0.265	0.196	**0.230**	0.273	0.208	**0.241**	0.269	0.202	**0.236**
T_2	0.309	0.237	**0.273**	0.318	0.239	**0.279**	0.314	0.238	**0.276**
T_3	0.302	0.249	**0.276**	0.327	0.255	**0.291**	0.315	0.252	**0.283**
T_4	0.337	0.268	**0.303**	0.352	0.272	**0.312**	0.344	0.270	**0.307**
T_5	0.301	0.223	**0.262**	0.307	0.229	**0.268**	0.304	0.226	**0.265**
T_6	0.278	0.212	**0.245**	0.287	0.222	**0.255**	0.283	0.217	**0.250**
T_7	0.282	0.220	**0.251**	0.284	0.218	**0.251**	0.283	0.219	**0.251**
T_8	0.297	0.228	**0.262**	0.305	0.235	**0.270**	0.301	0.232	**0.266**
T_9	0.268	0.201	**0.235**	0.275	0.212	**0.244**	0.272	0.207	**0.239**
T_{10}	0.262	0.190	**0.226**	0.271	0.198	**0.235**	0.267	0.194	**0.231**
Mean	**0.290**	**0.222**	**0.256**	**0.300**	**0.229**	**0.264**	**0.295**	**0.226**	
$CD_{0.05}$									
Year	0.001								
Treatment	0.002								
Condition	0.001								
Year × Treatment	0.003								
Year × Condition	0.001								
Treatment × Condition	0.003								
Year × Treatment × Condition	0.004								

T_1: Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis), **T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis, **T_8**: Goat manure and RDN on 50:50 equivalence basis, **T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

During the year 2022, treatment effect revealed that lowest electrical conductivity was recorded under treatment T_{10} (0.235 dS m^{-1}) whereas highest electrical conductivity was recorded under T_4 (0.312 dS m^{-1}). Under different planting condition; minimum electrical conductivity was recorded in C_2 (0.229 dS m^{-1}) and maximum electrical conductivity was recorded in C_1 (0.300 dS m^{-1}). Interaction between the treatment and planting condition (T×C) showed that treatment combination $T_{10}C_2$ (0.198 dS m^{-1}) was having lowest electrical conductivity while highest electrical conductivity was found in T_4C_2 (0.352 dS m^{-1}).

Pooled data of both the years revealed that among different treatments, T_{10} (0.231 dS m^{-1}) recorded minimum and T_4 (0.307 dS m^{-1}) maximum electrical conductivity. Under different planting condition, open condition showed lowest (0.226 dS m^{-1}) electrical conductivity when compared to agroforestry system (0.295 dS m^{-1}). Cumulative effect of treatment and condition (T×C) depicts that treatment combination $T_{10}C_2$ (0.194 dS m^{-1}) recorded minimum electrical conductivity and maximum electrical conductivity was recorded in T_4C_1 (0.344 dS m^{-1}).

In general, electrical conductivity was low in the 2021 (0.256 dS m^{-1}) than the year 2022 (0.264 dS m^{-1}). Considering the interaction effect of year and planting condition (Y×C) revealed that electrical conductivity was lowest in Y_1C_2 (0.222 dS m^{-1}) whereas highest under Y_2C_1 (0.300 dS m^{-1}). Combine effect of year and treatment (Y×T) minimum electrical conductivity was recorded in year 2021 under Y_1T_{10} (0.226 dS m^{-1}) and maximum in year 2022 under Y_2T_4 (0.312 dS m^{-1}). Interaction between year treatment and planting condition recorded minimum electrical conductivity under $Y_1T_{10}C_2$ (0.190 dS m^{-1}) and maximum under $Y_2T_4C_1$ (0.352 dS m^{-1}).

Study revealed that soil electrical conductivity was higher under agroforestry system as compared to open condition. Results are in accordance with the observation made by Rahangdale (2016) in different Agri-silviculture practices in Jabalpur, where soil electrical conductivity under tree-based system was high as compared to fields with sole agricultural crops. These results also corroborate the findings of Bisht *et al.* (2017), Kumar *et al.* (2019) and Yadav *et al.* 2019, who observed higher soil electrical conductivity under agroforestry when compared to open condition. According to Arnold *et al.* (2005), soil electrical conductivity, which measures salt concentration, is regarded as a simple to measure and reliable indicator of soil quality. In the present study, increase in the electrical conductivity was observed with the application of nutrient sources, where the highest values were recorded under organic manures. The results of the finding are in consonance with Sharma *et al.* (2020) and Aziz *et al.* (2019) where they reported that application of 100 % recommended dose of nitrogen through organic manure results in highest electrical conductivity in soil. The possible explanation for increase in electrical conductivity might be due to increase in base saturation of the soil where optimum rate of fertilizer and manure was applied compared to control plots.

4.3.3 Bulk density (g cm^{-3})

Data itemized in Table 20 revealed that year, treatment and planting condition had significant effect on soil bulk density. In year 2021, among planting conditions, higher bulk density was recorded in C_2 (1.10 g cm^{-3}) and lower in C_1 (1.03 g cm^{-3}), however among different treatments, it was highest in T_{10} (1.26 g cm^{-3}) whereas lowest in T_4 (0.94 g cm^{-3}). Meanwhile considering the interaction effect between the treatment and planting condition (T×C), maximum bulk density was recorded in $T_{10}C_2$ (1.32 g cm^{-3}) and minimum in T_4C_1 (0.90 g cm^{-3}) being statistically at par with T_3C_1.

Continuing to the year 2022, same trends were noticed, where among planting conditions higher bulk density was recorded in C_2 (1.06 g cm^{-3}) and lower in C_1 (1.00 g cm^{-3}). Consequently, treatment effect revealed that maximum bulk density was recorded under T_{10} (1.23 g cm^{-3}) and minimum under T_4 (0.90 g cm^{-3}), however combined effect of treatment and planting condition (T×C) portrayed that treatment combination $T_{10}C_2$ (1.30 g cm^{-3}) was having highest while T_4C_2 (0.86 g cm^{-3}) recorded the lowest bulk density, respectively.

Pooled data of both the years showed that among different planting condition, open condition (1.08 g cm^{-3}) showed higher bulk density when compared to agroforestry system (1.01 g cm^{-3}). Result compares with the study conducted by the Koul *et al.* (2011) in Terai zone of West Bengal, where bulk density under different agroforestry practices was lower when compared to sole cropping system. Similarly, under different treatments, T_{10} recorded highest bulk density (1.25 g cm^{-3}) and T_4 recorded the lowest (0.92 g cm^{-3}). Cumulative effect of treatment and condition (T×C) depicted that treatment combination T_4C_1 recorded minimum (0.88 g cm^{-3}) bulk density and $T_{10}C_2$ recorded the maximum (1.31 g cm^{-3}).

Table 20: Effect of organic manures and planting conditions on bulk density (g cm^{-3})

Treatments / Conditions	2021 (Y_1)			2022 (Y_2)			Pooled		
	Agroforestry system (C_1)	Open (C_2)	Mean	Agroforestry system (C_1)	Open (C_2)	Mean	Agroforestry system (C_1)	Open (C_2)	Mean
T_1	1.17	1.25	**1.21**	1.16	1.23	**1.19**	1.16	1.24	**1.20**
T_2	0.94	1.01	**0.97**	0.91	0.99	**0.95**	0.93	1.00	**0.96**
T_3	0.90	1.00	**0.95**	0.89	0.96	**0.93**	0.90	0.98	**0.94**
T_4	0.90	0.97	**0.94**	0.86	0.94	**0.90**	0.88	0.96	**0.92**
T_5	1.05	1.07	**1.06**	1.02	1.05	**1.03**	1.03	1.06	**1.05**
T_6	1.11	1.20	**1.16**	1.09	1.12	**1.11**	1.10	1.16	**1.13**
T_7	1.03	1.13	**1.08**	1.01	1.06	**1.04**	1.02	1.09	**1.06**
T_8	0.96	1.07	**1.02**	0.92	1.02	**0.97**	0.94	1.04	**0.99**
T_9	1.15	1.17	**1.16**	1.12	1.15	**1.14**	1.14	1.16	**1.15**
T_{10}	1.20	1.32	**1.26**	1.17	1.30	**1.23**	1.18	1.31	**1.25**
Mean	**1.03**	**1.10**	**1.06**	**1.00**	**1.06**	**1.03**	**1.01**	**1.08**	
$CD_{0.05}$									
Year	0.01								
Treatment	0.02								
Condition	0.01								
Year × Treatment	Non-significant								
Year × Condition	Non-significant								
Treatment × Condition	0.03								
Year × Treatment × Condition	0.02								

T_1: Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis), **T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis, **T_8**: Goat manure and RDN on 50:50 equivalence basis, **T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

Further it has been noticed that highest bulk density was recorded in year 2021 (1.06 g cm^{-3}) as compared to 2022 (1.03 g cm^{-3}). The interaction between year and planting condition (Y×C) as well as year and treatment (Y×T) registered a non-significant effect on bulk density. Lastly, interaction between year, treatment and planting condition (Y×T×C) registered significant effect on soil bulk density; being minimum in $Y_2T_4C_1$ (0.86 g cm^{-3}) and maximum in $Y_1T_{10}C_2$ (1.32 g cm^{-3}).

It was observed that the addition of organic manures alone or integrated with mineral fertilizer decreased bulk density of the soil. The results corroborated with the finding of Widowati *et al.* (2020) and Azuka and Idu (2022), they reported that adding organic amendments such compost, manures and biochar enhanced the amount of available water in the soil, increased porosity thereby reduced the soil bulk density. Similarly, the result also fits well with the findings of Mengistu *et al.* (2017), who found that the control plots had the highest soil bulk density (1.28 g cm^{-3}), whereas the vermi-compost mixed with mineral fertiliser plots had the lowest (1.24 g cm^{-3}) soil bulk density. The results are also in agreement with the Channal *et al*. (2016) and Bhatt *et al*. (2019) who found decreased soil bulk density due to addition of organic manures and inorganic fertilizers in the soil. According to Agbede *et al*. (2008) and Sankaramoorthy and Rangasamy (2019), improved soil aggregation, structural improvement, and greater porosity were the causes of the reduced bulk density with the application of organic manures.

4.3.4 Moisture content (%)

Appraisal of data presented in Table 21 reflects that year, treatment and planting condition significantly influenced the soil moisture content. During the year 2021, among different treatments minimum moisture content was observed in T_{10} (7.51 %) and maximum in T_2 (9.66 %). Counting to the different planting condition lower moisture content was observed in C_2 (7.81 %) followed by C_1 (8.81 %). During the year 2022, treatment effect revealed that minimum moisture content was recorded under treatment T_{10} (7.82 %) whereas maximum was recorded under T_2 (10.44 %). Under different planting condition; lower moisture content was recorded in C_2 (8.40 %) whereas, C_1 (9.61 %) recorded high moisture content.

Pooled data of both the years revealed that among different treatments, T_{10} (7.66 %) recorded minimum and T_2 (10.05 %) maximum moisture content. Under different planting condition, open condition showed low (8.11 %) moisture content when compared to agroforestry system (9.21 %).

In general, moisture content was lower in the 2021 (8.31 %) than the year 2022 (9.01 %). Considering the interaction effect of year and planting condition (Y×C) revealed that moisture content was lowest in Y_1C_2 (7.81 %) whereas highest under Y_2C_1 (9.61 %). Combine effect of year and treatment (Y×T) showed minimum moisture content in year 2021 under Y_1T_{10} (7.51 %) and maximum in year 2022 under Y_2T_2 (10.44 %). Interaction between year treatment and planting condition recorded minimum moisture content under $Y_1T_{10}C_2$ (6.96 %) and maximum under $Y_2T_2C_1$ (11.04 %).

Among two planting conditions, higher moisture content was recoded under agroforestry system as compared to control. The increased moisture content in tree-based system may be attributed to reduction of evapo-transpiration through canopy shade. Another possible reason of this can be the yearly addition of organic matter to the soil by trees in form of leaf-litter and its decomposition might have improved soil structure and moisture holding capacity of the soil (Misra, 2011). Similar results were reported by the Zhang *et al*. (2018) and Sarto *et al.* (2022), who recorded higher soil moisture content under agroforestry when compared to monoculture.

The results are consistent with the findings of the Ganiger *et al*. (2012), Channal *et al*. (2016), Jagadeesha *et al*. (2019) and Garima *et al*. (2021), where significantly higher water holding capacity of soil was recorded in the treatment with 100 percent RDN through organic manures when compared to inorganic fertilizers. The results are also in harmony with the Sharma *et al*. (2020), where the maximum soil moisture (10.93 % and 10.77 %) was recorded in T_3 (25 t FYM ha^{-1}) and the minimum soil moisture (8.29 % and 8.17 %) was observed in T_7 (control-no manure). The plausible reason for this might be the addition of organic manure reduce bulk density of soil due to higher organic matter content of soil added through manures and increase water holding capacity due to humic substances penetrated the inter lamella space of soil constituents and ultimately increase the water holding capacity of the soil (Sankaramoorthy and Rangasamy, 2019).

Table 21: Effect of organic manures and planting conditions on soil moisture content (%)

Treatments / Conditions	2021 (Y_1)			2022 (Y_2)			Pooled		
	Agroforestry system (C_1)	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**
T_1	8.23	7.26	**7.75**	9.03	7.78	**8.40**	8.63	7.52	**8.08**
T_2	10.14	9.18	**9.66**	11.04	9.83	**10.44**	10.59	9.51	**10.05**
T_3	9.29	8.31	**8.80**	10.16	8.92	**9.54**	9.73	8.61	**9.17**
T_4	9.58	8.57	**9.08**	10.44	9.22	**9.83**	10.01	8.90	**9.45**
T_5	8.45	7.46	**7.96**	9.32	8.08	**8.70**	8.89	7.77	**8.33**
T_6	8.92	7.91	**8.42**	9.77	8.56	**9.17**	9.35	8.24	**8.79**
T_7	8.48	7.50	**7.99**	9.32	8.15	**8.73**	8.90	7.83	**8.36**
T_8	8.56	7.60	**8.08**	9.42	8.23	**8.83**	8.99	7.92	**8.45**
T_9	8.37	7.39	**7.88**	9.23	8.04	**8.63**	8.80	7.72	**8.26**
T_{10}	8.06	6.96	**7.51**	8.40	7.24	**7.82**	8.23	7.10	**7.66**
Mean	**8.81**	**7.81**	**8.31**	**9.61**	**8.40**	**9.01**	**9.21**	**8.11**	
$CD_{0.05}$									
Year	0.03								
Treatment	0.01								
Condition	0.01								
Year × Treatment	0.04								
Year × Condition	0.02								
Treatment × Condition	Non-significant								
Year × Treatment × Condition	0.05								

T_1: Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis), **T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis, **T_8**: Goat manure and RDN on 50:50 equivalence basis, **T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

4.2.5 Organic carbon (%)

As evident from the Table 22, organic carbon was influenced significantly with the year, application of different manure sources, planting conditions and their interactions. Pertaining to the year 2021, among different planting conditions, organic carbon was highest C_1 (0.66 %) while lowest in C_2 (0.60 %), however among different doses of manures it was maximum in T_4 (0.77 %) whereas minimum in T_{10} (0.49 %). Meanwhile considering the interaction effect between the treatment and planting condition (T×C), highest organic carbon was recorded in treatment combination T_4C_1 (0.79 %) while lowest in $T_{10}C_2$ (0.48 %).

In the data recorded for the year 2022 same trends were observed, where among planting conditions highest organic carbon was recorded in C_1 (0.76 %) and lowest in C_2 (0.64 %). Consequently, treatment effect revealed that maximum organic carbon was recorded under T_4 (0.85 %) and minimum under T_{10} (0.53 %), however combined effect of treatment and planting condition (T×C) portrayed that treatment combination T_4C_1 (0.92 %) was having highest while $T_{10}C_2$ (0.50 %) recorded the lowest organic carbon, respectively.

Pooled data of both the years showed that among two planting conditions, agroforestry system (0.71 %) showed higher organic carbon when compared to open condition (0.62 %). Similarly, under different treatments, T_4 recorded maximum organic carbon (0.81 %) and T_{10} recorded the minimum (0.51 %) organic carbon. Cumulative effect of treatment and condition (T×C) depicted that treatment combination T_4C_1 (0.86 %) recorded highest organic carbon and $T_{10}C_2$ (0.49 %) recorded the lowest organic carbon.

Further it has been noticed that highest organic carbon was recorded in year 2022 (0.70 %) as compared to 2021 (0.63 %). The interaction between year and planting condition (Y×T) registered a non-significant effect on organic carbon. The composite effect of year and treatment (Y×C) recorded; minimum organic carbon under Y_1C_2 (0.60 %) and maximum under Y_2C_1 (0.76 %). Lastly, interaction between year, treatment and planting condition (Y×T×C) laid no significant effect on organic carbon.

Table 22: Effect of organic manures and planting conditions on soil organic carbon (%)

Treatments / Conditions	2021 (Y_1)			2022 (Y_2)			Pooled		
	Agroforestry system (C_1)	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**
T_1	0.54	0.50	**0.52**	0.61	0.52	**0.56**	0.57	0.51	**0.54**
T_2	0.78	0.71	**0.75**	0.88	0.75	**0.81**	0.83	0.73	**0.78**
T_3	0.75	0.69	**0.72**	0.85	0.73	**0.79**	0.80	0.71	**0.75**
T_4	0.79	0.74	**0.77**	0.92	0.78	**0.85**	0.86	0.76	**0.81**
T_5	0.73	0.66	**0.69**	0.82	0.71	**0.77**	0.78	0.68	**0.73**
T_6	0.67	0.59	**0.63**	0.78	0.63	**0.71**	0.72	0.61	**0.67**
T_7	0.61	0.54	**0.58**	0.71	0.59	**0.65**	0.66	0.57	**0.61**
T_8	0.70	0.62	**0.66**	0.80	0.68	**0.74**	0.75	0.65	**0.70**
T_9	0.56	0.51	**0.54**	0.64	0.55	**0.60**	0.60	0.53	**0.57**
T_{10}	0.50	0.48	**0.49**	0.57	0.50	**0.53**	0.54	0.49	**0.51**
Mean	**0.66**	**0.60**	**0.63**	**0.76**	**0.64**	**0.70**	**0.71**	**0.62**	
$CD_{0.05}$									
Year	0.01								
Treatment	0.02								
Condition	0.01								
Year × Treatment	Non-significant								
Year × Condition	0.01								
Treatment × Condition	0.02								
Year × Treatment × Condition	Non-significant								

T_1: Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis), **T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis, **T_8**: Goat manure and RDN on 50:50 equivalence basis, **T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

The results are in accordance with the studies conducted by the Koul *et al*. (2011) and Dhillon and Van Rees (2017) in West Bengal and Saskatchewan respectively, where SOC under different agroforestry practices was higher compared to sole cropping system. High content of SOC could be ascribable to leaf litter production which decomposes to produce high SOC content. The result also fits well with the findings of the Gupta and Sharma (2009), Sirohi and Bangarwa (2017) and Zahoor *et al*., (2021) who reported higher soil organic carbon under agroforestry system than the open condition. Other possible reason for this might be microenvironment created by the tree component in AFS, which result in lower temperature under the tree canopy which reduce the volatilization of different nutrient in the soil.

In addition, present investigation indicates an increase in organic carbon with application of organic sources of nutrients. A possible reason for this is application of organic manure enhance the synergistic effect among soil aggregates, organic carbon and enzymes involves in carbon which is beneficial for soil organic carbon sequestration (Zhao *et al*., 2020). Another explanation for this is that the addition of organic manure result in direct input of humic carbon into the soil. Thus, shortening the process of humus formation and accumulation. The results are in consonance with the findings of Li *et al*. (2018) and Hernandez *et al*. (2021), they reported that the organic matter content was higher in organic fertilizer treatments than in chemical fertilizer treatments. This could be brought on by the higher levels of organic carbon and microbial biomass carbon that organic manures contribute and also increased above and below ground carbon input resulted in long-term nutrient accumulation.

4.2.6 Available nitrogen (kg ha^{-1})

Nitrogen is one of the major plant nutrients taken up by plants in greatest quantity next to carbon, oxygen and hydrogen required for the growth and development. Plants receiving insufficient nitrogen are stunted in growth and possess poor root system (Mengel and Kirkby, 1987). Nitrogen is very essential for proper growth and development of plants because it contributes significantly to the structural makeup of proteins and involved in a variety of metabolic processes that effect crop productivity and yield as a whole (Barker and Pilbeam, 2007).

Appraisal of data presented in Table 23 reflects that year, treatment and planting condition significantly influenced the availability nitrogen in the soil. During the year 2021, among different doses of manures; minimum available nitrogen was observed in T_{10} (258.28 kg ha^{-1}) and maximum in T_4 (354.16 kg ha^{-1}). While counting to the two planting conditions, available nitrogen was less in C_2 (301.47 kg ha^{-1}) when compared to C_1 (314.71 kg ha^{-1}). However, the cumulative effect of treatment and planting condition (T×C), recorded minimum available nitrogen in $T_{10}C_2$ (255.74 kg ha^{-1}) and maximum in T_4C_1 (362.12 kg ha^{-1}).

In the year 2022 same trends were noticed where lower available nitrogen was recorded in C_2 (314.96 kg ha^{-1}) as compared to C_1 (327.65 kg ha^{-1}). Treatment effect revealed that minimum available nitrogen was recorded under T_{10} (262.39 kg ha^{-1}) whereas maximum under T_4 (370.11 kg ha^{-1}). Combined effect of treatment and planting condition (T×C) showed that treatment combination $T_{10}C_2$ (259.85 kg ha^{-1}) was having lowest available nitrogen while highest in T_4C_2 (378.10 kg ha^{-1}).

Pooled data of both the year reflects that among different planting conditions; higher available nitrogen was recorded in C_1 (321.18 kg ha^{-1}) and lower in C_2 (308.22 kg ha^{-1}). However, under different manure doses, T_4 (362.13 kg ha^{-1}) recorded highest available nitrogen and T_{10} (260.33 kg ha^{-1}) recorded the lowest. Whereas, cumulative effect of treatment and condition (T×C) depicts that $T_{10}C_2$ recorded minimum (257.79 kg ha^{-1}) available nitrogen and maximum (370.11 kg ha^{-1}) was recorded in T_4C_1.

In general, available nitrogen was higher in year 2022 (321.31 kg ha^{-1}) than the year 2021 (308.09 kg ha^{-1}). Meanwhile, interaction between year and treatment (Y×T) recorded, minimum available nitrogen in Y_1T_{10} (258.28 kg ha^{-1}) and maximum in Y_2T_4 (370.11 kg ha^{-1}). Whereas, interaction effect between the year and condition (Y×C) as well as year, treatment and planting condition (Y×T×C) were found to be non-significant.

The results of the study are in harmony with the Bhat (2015), Bisht *et al*. (2017) and Garima *et al*. (2021) who reported higher available nitrogen under agroforestry system when compared to sole cropping. This could be due to the yearly accretion of leaf litter in agroforestry system due to trees and its rapid decomposition help in build-up of nitrogen in the soil (Kaushal *et al*., 2016). Another possible reason for this could be the check provided by the tree canopy which inhibits the loss of nitrogen through volatilization process. Higher

Table 23: Effect of organic manures and planting conditions on available nitrogen (kg/ha)

Treatments / Conditions	2021 (Y_1)			2022 (Y_2)			Pooled		
	Agroforestry system (C_1)	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**
T_1	301.77	286.84	**294.31**	316.71	301.77	**309.24**	309.24	294.31	**301.77**
T_2	344.46	331.51	**337.99**	357.41	344.46	**350.94**	350.94	337.99	**344.46**
T_3	337.57	321.70	**329.64**	353.44	338.57	**346.01**	345.51	330.14	**337.82**
T_4	362.12	346.20	**354.16**	378.10	362.12	**370.11**	370.11	354.16	**362.13**
T_5	293.06	280.21	**286.63**	305.92	293.06	**299.49**	299.49	286.63	**293.06**
T_6	318.31	302.95	**310.63**	333.72	319.31	**326.52**	326.02	311.13	**318.57**
T_7	310.25	299.36	**304.81**	321.16	310.25	**315.71**	315.71	304.81	**310.26**
T_8	322.97	308.06	**315.51**	337.88	322.97	**330.42**	330.42	315.51	**322.97**
T_9	295.77	282.16	**288.96**	307.23	297.27	**302.25**	301.50	289.71	**295.61**
T_{10}	260.81	255.74	**258.28**	264.93	259.85	**262.39**	262.87	257.79	**260.33**
Mean	**314.71**	**301.47**	**308.09**	**327.65**	**314.96**	**321.31**	**321.18**	**308.22**	
$CD_{0.05}$									
Year	0.37								
Treatment	0.82								
Condition	0.37								
Year × Treatment	1.16								
Year × Condition	Non-significant								
Treatment × Condition	1.16								
Year × Treatment × Condition	Non-significant								

T_1: Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis), **T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis, **T_8**: Goat manure and RDN on 50:50 equivalence basis, **T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

available nitrogen content in agroforestry systems could be attributed to the higher content of SOC stock. The low available–N content in soils of sole cropping system could be attributed to the rapid turnover (mineralization) of the organic substrates derived from residue (root biomass) and also from external source following intensive cultivation (Gebeyaw, 2007).

Among different treatment, available nitrogen was higher under organic manures compared to other treatments. The present result corroborates the findings of Zhao *et al*. (2019), who investigated the effects of organic amendments on soil properties. They found that when compared to soil treated with only mineral fertilisers, organic amendments increased soil organic matter, nitrogen, water-stable aggregates, and macro-porosity. Singh and Mishra, (2012) conducted a study to assess the available macro nutrients and its correlation with soil organic carbon and found that SOC has positive correlation with available–N. Variations in available–N for different land use systems were also reported by Stevenson and Cole (1999). The author opined that, variations in available–N may be attributed to variation in soil organic matter and total–N contents. Similar results were reported by Hossain *et al*. (2018), Biratu *et al*. (2019) and Azuka and Idu (2022) where inclusion of organic amendments improved the available nitrogen in the soil.

4.2.7 Available phosphorus (kg ha^{-1})

Phosphorus is one of the major nutrients and the key factor for plant growth (Foth and Ellis, 1997). Next to N, P has more wide spread influence on both natural and agricultural ecosystems than any other essential elements. The data on the available phosphorus as influenced by imposition of different year, manure treatments and planting conditions, presented in the Table 24. It indicates significant effect of year, treatment and planting conditions on available phosphorus. Pertaining to the year 2021, among different planting condition higher (50.56 kg ha^{-1}) available phosphorus was recorded in C_1 and lower (47.22 kg ha^{-1}) in C_2. Among different manure treatments maximum available phosphorus was observed in treatment T_4 (62.86 kg ha^{-1}) whereas available phosphorus was minimum in treatment T_{10} (38.96 kg ha^{-1}). Under the interaction between the treatment and planting condition (T×C); maximum available phosphorus was recorded in treatment combination T_4C_1 (64.86 kg ha^{-1}) while minimum available phosphorus was recorded in $T_{10}C_2$ (37.80 kg ha^{-1}).

Table 24: Effect of organic manures and planting conditions on available phosphorus (kg/ha)

Treatments / Conditions	2021 (Y_1)			2022 (Y_2)			Pooled		
	Agroforestry system (C_1)	Open (C_2)	Mean	Agroforestry system (C_1)	Open (C_2)	Mean	Agroforestry system (C_1)	Open (C_2)	Mean
T_1	41.22	38.92	**40.07**	43.34	41.23	**42.29**	42.28	40.08	**41.18**
T_2	55.83	52.17	**54.00**	60.38	56.52	**58.45**	58.11	54.35	**56.23**
T_3	61.19	57.83	**59.51**	66.43	63.07	**64.75**	63.81	60.45	**62.13**
T_4	64.86	60.86	**62.86**	70.18	66.46	**68.32**	67.52	63.66	**65.59**
T_5	54.29	51.02	**52.66**	58.64	55.04	**56.84**	56.47	53.03	**54.75**
T_6	44.82	41.02	**42.92**	48.42	45.13	**46.78**	46.62	43.08	**44.85**
T_7	48.61	45.14	**46.88**	53.28	49.71	**51.50**	50.94	47.43	**49.19**
T_8	51.50	47.86	**49.68**	56.42	52.57	**54.50**	53.96	50.22	**52.09**
T_9	43.18	39.57	**41.37**	46.13	42.56	**44.34**	44.65	41.06	**42.86**
T_{10}	40.12	37.80	**38.96**	41.65	39.28	**40.47**	40.89	38.54	**39.71**
Mean	**50.56**	**47.22**	48.89	**54.49**	**51.16**	**52.82**	**52.52**	**49.19**	
$CD_{0.05}$									
Year	0.33								
Treatment	0.74								
Condition	0.33								
Year × Treatment	1.04								
Year × Condition	0.47								
Treatment × Condition	Non-significant								
Year × Treatment × Condition	Non-significant								

T_1: Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis), **T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis, **T_8**: Goat manure and RDN on 50:50 equivalence basis, **T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

In the year 2022, among planting conditions available phosphorus was higher in C_1 (54.49 kg ha^{-1}) and lower in C_2 (51.16 kg ha^{-1}). Treatment, effect revealed that maximum available phosphorus was recorded under treatment T_4 (68.32 kg ha^{-1}) whereas, minimum available phosphorus was recorded under T_{10} (40.47 kg ha^{-1}). Combined effect of treatment and planting condition (T×C) showed that treatment combination T_4C_1 (70.18 kg ha^{-1}) was having highest available phosphorus while lowest was found in $T_{10}C_2$ (39.28 kg ha^{-1}).

Pooled data of both the years showed that among different planting condition, open condition recorded lower (49.19 kg ha^{-1}) available phosphorus as compared to agroforestry system (52.52 kg ha^{-1}). Under different treatments, T_4 (65.59 kg ha^{-1}) recorded highest available phosphorus and T_{10} (39.71 kg ha^{-1}) lowest available phosphorus. Cumulative effect of treatment and condition (T×C) depicts that treatment combination T_4C_1 (67.52 kg ha^{-1}) recorded maximum available phosphorus and minimum available phosphorus was recorded in $T_{10}C_2$ (38.54 kg ha^{-1}).

Further it has been noticed that higher (52.82 kg ha^{-1}) available phosphorus was recorded in year 2022 as compared to year 2021 (48.89 kg ha^{-1}). Interaction between year and planting condition (Y×C) had no significant on available phosphorus; maximum available phosphorus was recorded in Y_2C_1 (54.49 kg ha^{-1}) and minimum available phosphorus was recorded in Y_1C_2 (47.22 kg ha^{-1}). Composite effect of year and treatment (Y×T) showed highest available phosphorus under Y_2T_4 (68.32 kg ha^{-1}) whereas lowest under Y_1T_{10} (38.96 kg ha^{-1}). Interaction between year, treatment and planting condition (Y×T×C) registered no significant effect on soil available phosphorus; maximum available phosphorus was recorded in $Y_2T_4C_1$ (70.18 kg ha^{-1}) and minimum in $Y_1T_{10}C_2$ (37.80 kg ha^{-1}).

Sureshbhai *et al*. (2017) conducted the similar study in Gujarat and reported that phosphorus content was higher in different agroforestry system when compared to sole cropping system. Higher amount of phosphorus could be attributed to the presence of higher SOC content in agroforestry system. Gairola *et al*. (2012) and Shelukindo *et al*. (2014), reported that organic matter content strongly influences phosphorus. They found strong positive and significant correlation obtained between available – P_2O_5 with soil organic carbon content. The positive correlation with available – P_2O_5 is due to the fact that phosphorus can be specifically adsorbed by soil colloids, including humus. The results obtained are also in accordance with the findings of Bini *et al*. (2018) and Kar *et al*. (2018), who reported higher available phosphorus under agroforestry system when compared to sole cropping. This might be due to potential of woody perennial component to absorb phosphate ions from deeper soil layers and pump them back to upper layers via decomposition of litter fall. The trees improve rhizosphere by adding organic matter through the influence of roots, litter fall and root exudates, which acts as substrates for different organisms engaged in mineralization process resulting in release of nutrients (Garima *et al*., 2021).

Overall, it was found that available phosphorus was highest under organic manure treatments. The observations are in agreement with the findings of Nemera *et al*. (2018) and Sharma *et al*. (2020) who registered significant increase in available phosphorous with application of organic manures to the soil. The plausible reason for this is the reduced fixing of the phosphorus. This can be explained by the findings of Wagari *et al*. (2022), who reported that increased phosphorous content of the soil might be due to the increase in organic acids during decomposition of organic manures which helped in releasing phosphorus. Similarly, Toor *et al*. (2006) also observed increase in C, N and available P contents in a long-term experiment with long-lasting applications of organic wastes. The organic components enhance soil aggregation and raise the nutritional content of the soil. Additionally, these organic components promote bacterial and fungal growth as well as general and targeted soil microbial activity (Hernandez *et al*., 2021). Higher available phosphorus in organically managed soils might be attributed to greater soil water content, higher nutrient availability and more protection from erosion compared to conventional and control treatments. With organically managed soils, soil nutrients are released slowly over time. Whereas the chemical fertilizers are easily water soluble, this may lead to various types of losses through leaching, evaporation etc., in conventional farming (Kyi and Aung, 2017).

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

Potassium is another major macro nutrient required for plant growth that also limit plant productivity. Unlike N and P, K causes no off-site environmental problems when it leaves the soil system. It is non-toxic and does not cause eutrophication in aquatic systems (Tisdale *et al.,* 1995). A cursory look at the Table 25 shows that year, treatment, planting condition had significant effect on available potassium. During the year 2021, among different planting conditions, higher available potassium was recorded in C_1 (238.01 kg ha^{-1}) than in C_2 (232.48 kg ha^{-1}), however among different doses of manures it was highest in T_4 (282.53 kg ha^{-1}) whereas lowest in T_{10} (204.63 kg ha^{-1}). Meanwhile considering the interaction effect between the treatment and planting condition (T×C), maximum available potassium was recorded in treatment combination T_4C_1 (286.79 kg ha^{-1}) and minimum in $T_{10}C_2$ (202.80 kg ha^{-1}).

In the data recorded for the year 2022 same trends were observed, where among planting conditions higher available potassium was recorded in C_1 (241.99 kg ha^{-1}) and lower in C_2 (236.47 kg ha^{-1}). Consequently, treatment effect revealed that maximum available potassium was recorded under T_4 (288.46 kg ha^{-1}) and minimum under T_{10} (206.34 kg ha^{-1}), however combined effect of treatment and planting condition (T×C) portrayed that treatment combination T_4C_1 (292.73 kg ha^{-1}) was having highest while $T_{10}C_2$ (204.51 kg ha^{-1}) recorded the lowest available potassium, respectively.

Pooled data of both the years showed that among different plantings condition, agroforestry system (240.00 kg ha^{-1}) showed more available potassium compared to open condition (234.48 kg ha^{-1}). Similarly, under different treatments, T_4 recorded highest available potassium (285.50 kg ha^{-1}) and T_{10} recorded the lowest (205.49 kg ha^{-1}). Cumulative effect of treatment and condition (T×C) depicted that treatment combination T_4C_1 recorded maximum (289.76 kg ha^{-1}) available potassium and $T_{10}C_2$ recorded the minimum (203.66 kg ha^{-1}).

Further it has been noticed that higher available potassium was recorded in year 2022 (239.23 kg ha^{-1}) as compared to 2021 (235.24 kg ha^{-1}). The interaction between year and planting condition (Y×C) registered a non-significant effect on available potassium. The composite effect of year and treatment (Y×T) recorded; minimum available potassium in year 2021 under Y_1T_{10} (204.63 kg ha^{-1}) and maximum in year 2022 under Y_2T_4 (288.46 kg ha^{-1}). Lastly, interaction between year, treatment and planting condition (Y×T×C) laid significant effect on available potassium, being minimum in $Y_2T_4C_1$ (292.73 kg ha^{-1}) and maximum in $Y_1T_{10}C_2$ (202.80 kg ha^{-1}).

Potassium plays crucial role in opening and closing of stomata, regulating plant water proportion, plant enzyme activities, effect photosynthesis, stability of plant membranes and osmotic potential (Jatav *et al*., 2014 and Erel *et al*., 2015). It was found that among the different agroforestry practices, available potassium content was significantly higher in agroforestry system than in open condition. Bhat (2015), Prakash (2015) and

Table 25: Effect of organic manures and planting conditions on available potassium (kg/ha)

Treatments / Conditions	2021 (Y_1)			2022 (Y_2)			Pooled		
	Agroforestry system (C_1)	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**
T_1	211.14	207.27	**209.20**	213.58	209.71	**211.65**	212.36	208.49	**210.43**
T_2	257.14	252.07	**254.61**	262.08	257.01	**259.55**	259.61	254.54	**257.08**
T_3	264.06	257.86	**260.96**	268.91	262.71	**265.81**	266.49	260.29	**263.39**
T_4	286.79	278.26	**282.53**	292.73	284.20	**288.46**	289.76	281.23	**285.50**
T_5	254.96	249.86	**252.41**	258.38	253.28	**255.83**	256.67	251.57	**254.12**
T_6	221.13	215.93	**218.53**	225.48	220.28	**222.88**	223.30	218.10	**220.70**
T_7	226.58	220.72	**223.65**	230.82	224.95	**227.89**	228.70	222.84	**225.77**
T_8	236.89	229.69	**233.29**	241.67	234.47	**238.07**	239.28	232.08	**235.68**
T_9	214.90	210.37	**212.63**	218.09	213.56	**215.83**	216.49	211.97	**214.23**
T_{10}	206.46	202.80	**204.63**	208.17	204.51	**206.34**	207.32	203.66	**205.49**
Mean	**238.01**	**232.48**	**235.24**	241.99	236.47	**239.23**	240.00	234.48	
$CD_{0.05}$									
Year	0.28								
Treatment	0.63								
Condition	0.28								
Year × Treatment	0.90								
Year × Condition	Non-significant								
Treatment × Condition	0.90								
Year × Treatment × Condition	1.27								

T_1: Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis), **T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis, **T_8**: Goat manure and RDN on 50:50 equivalence basis, **T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

Rahangdale (2016) conducted a similar study and reported higher potassium content under different agroforestry system when compared to sole cropping system. The possible reason for this is the mineralization of potassium in agri-silviculture systems due to the annual deposition of leaf litter and its subsequent decomposition (Garima *et al*., 2021). The results are also in line with the findings of Ginwal *et al*. (2019) and Bhakar *et al*. (2021).

The critical examination of the data showed higher content of available potassium in the soil treated with the organic manures. The results of the present findings are in consonance with Channal *et al*. (2016), Gaurav *et al*. (2019) and Adekiya *et al*. (2020) who reported that the soil treated with the organic manures recorded highest content of potassium when compared to inorganic fertilizers and control. Almeida *et al*. (2019) also stated that fertilization of soil with animal manure have the potential to supply P and K to plants. Mahmood *et al*. (2017) explicated that organic manures improve the nitrogen use efficiency, micro and macro nutrient recovery and help in phosphorus solubilization and its uptake by the plants and enhance potassium availability. Parewa *et al*. (2014) and Rajneesh *et al*., (2017) reported that application of organic manure improves cation exchange capacity of soil, which is more conductive to reduce leaching losses of potassium.

4.3 BIO-ECONOMIC APPRAISAL OF WILD POMEGRANATE-BASED AGROFORESTRY

4.3.1 Cost of cultivation (Rs ha^{-1})

A critical look at the data presented in Table 26 accentuates year, treatment, planting condition and their interaction effect on the cost of cultivation. Pertaining to the year 2021, among different planting conditions, cost of cultivation was higher in C_1 (Rs 82058.87 ha^{-1}) than in C_2 (Rs 69583.33 ha^{-1}), however among different doses of manures it was maximum in T_3 (Rs 112518.14 ha^{-1}) whereas minimum in T_{10} (Rs 48388.74 ha^{-1}). Meanwhile considering the interaction effect between the treatment and planting condition (T×C), highest cost of cultivation was recorded in treatment combination T_3C_1 (Rs 118755.91 ha^{-1}) and minimum in $T_{10}C_2$ (Rs 42150.97 ha^{-1}).

The data recorded for the year 2022 showed the same trends, where among different planting conditions, cost of cultivation was highest in C_1 (Rs 85803.87 ha^{-1}) and lowest in C_2 (Rs 69583.33 ha^{-1}). Consequently, treatment effect revealed that maximum cost of cultivation was recorded under T_3 (Rs 114390.64 ha^{-1}) and minimum under T_{10} (Rs 50261.24 ha^{-1}), however combined effect of treatment and planting condition (T×C) portrayed that treatment combination T_3C_1 (Rs 122500.91 ha^{-1}) was having highest while $T_{10}C_2$ (Rs 42150.97 ha^{-1}) recorded the lowest cost of cultivation, respectively.

Pooled data of both the years showed that among different planting condition, open condition (Rs 69583.33 ha^{-1}) showed less cost of cultivation when compared to agroforestry system (Rs 83931.37 ha^{-1}). Similarly, under different treatments, T_3 (Rs 113454.39 ha^{-1}) recorded highest cost of cultivation and T_{10} (Rs 49324.99 ha^{-1}) recorded the lowest cost of cultivation. Cumulative effect of treatment and condition (T×C) depicted that treatment combination T_3C_1 (Rs 120628.41 ha^{-1}) recorded maximum cost of cultivation and $T_{10}C_2$ (Rs 42150.97 ha^{-1}) recorded the minimum cost of cultivation.

It is evident from the results that costs of cultivation in organic manure treatments were higher in comparison to the cultivation of lemongrass with chemical fertilizers or integrated nutrient management (organic manure + inorganic fertilizers). The results of the present investigation are accordance with the findings of Vijaykumar *et al*. (2018), Ranjan *et al*. (2020) and Singh *et al*. (2020), they recorded higher cost of cultivation under organic manure treatment as compare to integrated nutrient management and control. The cost of cultivation in agroforestry was more than the sole cropping because of the additional cost incurred due to tree component. The results of the findings are in consonance with Kar *et al*. (2019) and Keprate (2021) and Gautam (2023), they reported higher cost of cultivation under agroforestry system than sole agriculture cropping.

4.3.2 Gross returns (Rs ha^{-1})

Data demonstrated in Table 27 showed the effect of year, treatment, planting condition and their interaction on gross returns. Pertaining to the year 2021, among different planting condition higher gross returns were recorded in C_2 (Rs 100506.90 ha^{-1}) and lower were recorded in C_1 (Rs 89744.63 ha^{-1}). Among different manure treatments, maximum gross returns were observed in treatment T_8 (Rs 139633.35 ha^{-1}) whereas minimum in T_{10} (Rs 49668.68 ha^{-1}). Cumulative effect of treatment and planting condition (T×C) recorded minimum gross returns in $T_{10}C_1$ (Rs 46196.78 ha^{-1}) and maximum in T_8C_2 (Rs 146302.20 ha^{-1}).

Table 26: Effect of organic manures on cost of cultivation (Rs ha^{-1}) in lemongrass under wild pomegranate-based agroforestry system

Conditions / Treatments	2021 (Y_1)			2022 (Y_2)			Pooled		
	Agroforestry system (C_1)	Open (C_2)	Mean	Agroforestry system (C_1)	Open (C_2)	Mean	Agroforestry system (C_1)	Open (C_2)	Mean
T_1	65591.51	53115.97	**59353.74**	69336.51	53115.97	**61226.24**	67464.01	53115.97	**60289.99**
T_2	111901.51	99425.97	**105663.74**	115646.51	99425.97	**107536.24**	113774.01	99425.97	**106599.99**
T_3	118755.91	106280.37	**112518.14**	122500.91	106280.37	**114390.64**	120628.41	106280.37	**113454.39**
T_4	83899.51	71423.97	**77661.74**	87644.51	71423.97	**79534.24**	85772.01	71423.97	**78597.99**
T_5	64901.51	52425.97	**58663.74**	68646.51	52425.97	**60536.24**	66774.01	52425.97	**59599.99**
T_6	88746.51	76270.97	**82508.74**	92491.51	76270.97	**84381.24**	90619.01	76270.97	**83444.99**
T_7	92173.71	79698.17	**85935.94**	95918.71	79698.17	**87808.44**	94046.21	79698.17	**86872.19**
T_8	74745.51	62269.97	**68507.74**	78490.51	62269.97	**70380.24**	76618.01	62269.97	**69443.99**
T_9	65246.51	52770.97	**59008.74**	68991.51	52770.97	**60881.24**	67119.01	52770.97	**59944.99**
T_{10}	54626.51	42150.97	**48388.74**	58371.51	42150.97	**50261.24**	56499.01	42150.97	**49324.99**
Mean	**82058.87**	**69583.33**	**75821.10**	**85803.87**	**69583.33**	**77693.60**	**83931.37**	**69583.33**	

T_1: Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis), **T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis, **T_8**: Goat manure and RDN on 50:50 equivalence basis, **T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

In the year 2022, among two planting conditions higher gross returns were recorded in C_1 (Rs 295715.07 ha^{-1}) as compared to C_2 (Rs 175823.64 ha^{-1}). Treatment, effect revealed that maximum gross returns were recorded under treatment T_8 (Rs 308400.75 ha^{-1}) whereas minimum gross returns were recorded under T_{10} (Rs 148074.00 ha^{-1}). Interaction between the treatment and planting condition (T×C) showed that treatment combination $T_{10}C_2$ (Rs 84860.33 ha^{-1}) was having lowest gross returns while highest gross returns were found in T_8C_1 (Rs 367233.38 ha^{-1}).

Pooled data of both the years showed that among different planting conditions, agroforestry system (Rs 192729.85 ha^{-1}) recorded higher gross returns when compared to open condition (Rs 138165.27 ha^{-1}). Under different treatments, T_8 (Rs 224017.05 ha^{-1}) recorded highest gross returns and T_{10} (Rs 98871.34 ha^{-1}) lowest gross returns. Cumulative effect of treatment and condition (T×C) depicts that treatment combination $T_{10}C_2$ (Rs 69000.45 ha^{-1}) recorded minimum gross returns and maximum gross returns were recorded in T_8C_1 (Rs 250098.94 ha^{-1}). Further it has been noticed that higher gross returns were recorded in year 2022 (Rs 235769.36 ha^{-1}) as compared to 2021 (Rs 95125.77 ha^{-1}).

It is evident from the Table 27 that gross returns of lemongrass in integrated nutrient treatments were higher in comparison to the gross returns with sole application of chemical fertilizers or organic manure. The results are consistent with the findings of Ramesh (2017), Vijaykumar *et al*. (2018) and Fazily and Hunshal (2019), who confirmed higher gross returns under integrate nutrient management. Pertaining to the year 2021, overall gross returns were higher in open condition as compared to the agroforestry, this was because during first year of planting, pomegranate trees did not bear any fruit therefore no returns were obtained from tree component. Pertaining to the year 2022, the gross returns in agroforestry were more than the sole cropping because of the additional returns obtained from the tree component. Higher returns from agroforestry system have also been reported by Dutt and Thakur (2004), Dhillon and Chauhan (2012), Armengot *et al*. (2016), Mozumder *et al*. (2017) and Yadav *et al*. (2018) as compared to sole cropping, which are in consonance with present results. Similarly, Solanki (2018) recorded higher economic returns under Sapota-Jatropha intercrop as compared to sole crops.

Table 27: Effect of organic manures on gross returns (Rs ha^{-1}) in lemongrass under wild pomegranate-based agroforestry system

Conditions / Treatments	2021 (Y_1)			2022 (Y_2)			Pooled		
	Agroforestry system (C_1)	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**
T_1	72318.60	80932.05	**76625.33**	263096.93	143912.33	**203504.63**	167707.76	112422.19	**140064.98**
T_2	78424.95	86196.90	**82310.93**	277668.38	159966.83	**218817.60**	178046.66	123081.86	**150564.26**
T_3	88763.70	99464.55	**94114.13**	295557.45	175362.00	**235459.73**	192160.58	137413.28	**164786.93**
T_4	99359.18	112732.58	**106045.88**	313142.85	195838.65	**254490.75**	206251.01	154285.61	**180268.31**
T_5	61380.23	72365.85	**66873.04**	254338.50	133426.88	**193882.69**	157859.36	102896.36	**130377.86**
T_6	104807.10	114183.00	**109495.05**	322801.05	204201.30	**263501.18**	213804.08	159192.15	**186498.11**
T_7	119754.00	133247.40	**126500.70**	346461.68	226818.15	**286639.91**	233107.84	180032.78	**206570.31**
T_8	132964.50	146302.20	**139633.35**	367233.38	249568.13	**308400.75**	250098.94	197935.16	**224017.05**
T_9	93477.30	106503.90	**99990.60**	305562.83	184281.83	**244922.33**	199520.06	145392.86	**172456.46**
T_{10}	46196.78	53140.58	**49668.68**	211287.68	84860.33	**148074.00**	128742.23	69000.45	**98871.34**
Mean	**89744.63**	**100506.90**	**95125.77**	**295715.07**	**175823.64**	**235769.36**	**192729.85**	**138165.27**	

T_1: Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis), **T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis, **T_8**: Goat manure and RDN on 50:50 equivalence basis, **T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

4.3.3 Net returns (Rs ha^{-1})

Data pertaining to the effect of year, treatment and planting condition on net returns have been presented in Table 28. In year 2021, among different planting conditions; maximum net returns were recorded in C_2 (Rs 30923.57 ha^{-1}) and minimum net returns were recorded in C_1 (Rs 7685.76 ha^{-1}). Among different treatments, highest net returns were observed in treatment T_8 (Rs 71125.61 ha^{-1}) whereas net returns were lowest in T_2 (Rs -23352.82 ha^{-1}). Under the interaction between the treatment and planting condition (T×C), maximum net returns were recorded in treatment combination T_8C_2 (Rs 84032.23 ha^{-1}) while minimum net returns were recorded inT_2C_1 (Rs -33476.56 ha^{-1}).

In the year 2022 opposite trends were noticed, where highest net returns were recorded in C_1 (Rs 209911.20 ha^{-1}) than those recorded in C_2 (Rs 106240.31 ha^{-1}). The treatment effect revealed that maximum net returns were recorded under treatment T_8 (Rs 238020.51 ha^{-1}) whereas, minimum net returns were recorded under T_{10} (Rs 97812.76 ha^{-1}). Combined effect of treatment and planting condition (T×C) showed that treatment combination T_8C_1 (Rs 288742.86 ha^{-1}) was having highest net returns while lowest net returns were found in $T_{10}C_2$ (Rs 42709.36 ha^{-1}).

Pooled data of both the years showed that among different planting condition, agroforestry system (Rs 108798.48 ha^{-1}) indicated more net returns compared to open condition (Rs 68581.94 ha^{-1}). Under different treatments, T_8 (Rs 154573.06 ha^{-1}) recorded highest net returns and T_2 (Rs 43964.27 ha^{-1}) lowest net returns. Cumulative effect of treatment and condition (T×C) depicts that treatment combination T_8C_1 (Rs 173480.93 ha^{-1}) recorded maximum net returns and minimum net returns were recorded in $T_{10}C_2$ (Rs 26849.48 ha^{-1}). Further it has been noticed that higher (Rs 158075.75 ha^{-1}) net returns were recorded in year 2022 as compared to year 2021 (Rs 19304.67 ha^{-1}).

The study revealed that the net returns in integrated nutrient management were higher as compared to the returns from the sole application of the organic manure and inorganic fertilizers. The results are in line with the findings of Choudhary *et al*. (2017), Altaf *et al*. (2019) and Anasuyamma *et al*. (2022), they recorded higher net returns under combine application of inorganic fertilizers with organic manures. Overall, during year 2021, higher net returns were recorded in open condition compared to agroforestry. This may be attributed to higher establishment cost and no gross returns from trees during first year of tree establishment. During 2022, higher net returns were recorded under agroforestry intervention, this could be attributed to the additional profit generated from tree component in comparison to the sole cropping devoid of trees. These results from the present study substantiate the previous findings of Kumar *et al*. (2004), Singh *et al*. (2017) and Chandana *et al*. (2020), they observed higher net returns under agroforestry systems as compared to sole agriculture cropping. Similar results were proposed by Chavan and Dhillon (2019), Kar *et al*. (2019) and Keprate (2021), who recorded higher net returns from *Grewia* based agroforestry system than sole cropping which validates the results of present study.

4.3.4 Benefit cost ratio (B:C)

Appraisal of data appended in Table 29 depicts the effect of year, treatment and planting condition on the benefit cost ratio. During the year 2021, among different doses of manures; minimum benefit cost ratio was observed in T_2 (0.78) and maximum in T_8 (2.06). While counting to the two planting conditions, benefit cost ratio was less in C_1 (1.12) compared to C_2 (1.51). However, the cumulative effect of treatment and planting condition (T×C), recorded minimum benefit cost ratio in T_2C_1 (0.70) and maximum in T_8C_2 (2.35).

In the year 2022 different trends were noticed where lowest benefit cost ratio was recorded in C_1 (3.57) as compared to C_2 (2.63). Treatment effect revealed that minimum benefit cost ratio was recorded under T_2 (2.00) whereas maximum under T_8 (4.34). Combined effect of treatment and planting condition (T×C) showed that treatment combination T_2C_2 (1.61) recorded lowest benefit cost ratio while highest in T_8C_1 (4.68).

Pooled data of both the year reflects that among different planting conditions; highest benefit cost ratio was recorded in C_1 (2.35) and lowest in C_2 (2.07). However, under different manure doses, T_8 (3.20) recorded highest benefit cost ratio and T_2 (1.39) recorded the lowest. Whereas, cumulative effect of treatment and condition (T×C) depicts that T_2C_2 recorded minimum (1.24) benefit cost ratio and maximum (3.23) was recorded in T_8C_1. In general, benefit cost ratio was higher in year 2022 (3.10) than the year 2021 (1.32).

The results are in agreement with the findings of Mahata *et al*. (2018), Parewa *et al*. (2019) and Singh *et al*. (2020), who recorded maximum B:C ratio under integrated nutrient management. These results also corroborate with the finding of Ranjan *et al*. (2020) who reported higher B:C ratio for treatment receiving 50 % N through inorganic fertilizers + 50 % N through organic manures. During the year 2021, benefit cost ratio was low in AFS due to high establishment cost incurred in raising tree and crop, while trees remained fruitless during first year, so no returns were obtained from tree component.

Table 28: Effect of organic manures on net returns (Rs ha^{-1}) in lemongrass under wild pomegranate-based agroforestry system

Conditions / Treatments	2021 (Y_1)			2022 (Y_2)			Pooled		
	Agroforestry system (C_1)	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**
T_1	6727.09	27816.08	**17271.58**	193760.41	90796.36	**142278.38**	100243.75	59306.22	**79774.98**
T_2	-33476.56	-13229.07	**-23352.82**	162021.86	60540.86	**111281.36**	64272.65	23655.89	**43964.27**
T_3	-29992.21	-6815.82	**-18404.02**	173056.54	69081.63	**121069.08**	71532.16	31132.91	**51332.53**
T_4	15459.66	41308.61	**28384.13**	225498.34	124414.68	**174956.51**	120479.00	82861.64	**101670.32**
T_5	-3521.29	19939.88	**8209.30**	185691.99	81000.91	**133346.45**	91085.35	50470.39	**70777.87**
T_6	16060.59	37912.03	**26986.31**	230309.54	127930.33	**179119.93**	123185.06	82921.18	**103053.12**
T_7	27580.29	53549.23	**40564.76**	250542.96	147119.98	**198831.47**	139061.63	100334.61	**119698.12**
T_8	58218.99	84032.23	**71125.61**	288742.86	187298.16	**238020.51**	173480.93	135665.19	**154573.06**
T_9	28230.79	53732.93	**40981.86**	236571.31	131510.86	**184041.08**	132401.05	92621.89	**112511.47**
T_{10}	-8429.74	10989.61	**1279.93**	152916.16	42709.36	**97812.76**	72243.21	26849.48	**49546.35**
Mean	**7685.76**	**30923.57**	**19304.67**	**209911.20**	**106240.31**	**158075.75**	**108798.48**	**68581.94**	

T_1: Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis), **T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis, **T_8**: Goat manure and RDN on 50:50 equivalence basis, **T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

Table 29: Effect of organic manures on B:C ratio in lemongrass under wild pomegranate-based agroforestry system

Conditions / Treatments	2021 (Y_1)			2022 (Y_2)			Pooled		
	Agroforestry system (C_1)	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**	**Agroforestry system (C_1)**	**Open (C_2)**	**Mean**
T_1	1.10	1.52	**1.31**	3.79	2.71	**3.25**	2.45	2.12	**2.28**
T_2	0.70	0.87	**0.78**	2.40	1.61	**2.00**	1.55	1.24	**1.39**
T_3	0.75	0.94	**0.84**	2.41	1.65	**2.03**	1.58	1.29	**1.44**
T_4	1.18	1.58	**1.38**	3.57	2.74	**3.16**	2.38	2.16	**2.27**
T_5	0.95	1.38	**1.16**	3.71	2.55	**3.13**	2.33	1.96	**2.14**
T_6	1.18	1.50	**1.34**	3.49	2.68	**3.08**	2.34	2.09	**2.21**
T_7	1.30	1.67	**1.49**	3.61	2.85	**3.23**	2.46	2.26	**2.36**
T_8	1.78	2.35	**2.06**	4.68	4.01	**4.34**	3.23	3.18	**3.20**
T_9	1.43	2.02	**1.73**	4.43	3.49	**3.96**	2.93	2.76	**2.84**
T_{10}	0.85	1.26	**1.05**	3.62	2.01	**2.82**	2.23	1.64	**1.93**
Mean	**1.12**	**1.51**	**1.32**	**3.57**	**2.63**	**3.10**	**2.35**	**2.07**	

T_1: Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis), **T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis, **T_8**: Goat manure and RDN on 50:50 equivalence basis, **T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

Whereas during year 2022, higher benefit cost ratio was recorded under agroforestry compared to open condition. The present results are in the consonance with the Pandey *et al*. (2016), Padma *et al*. (2018), Akter *et al*. (2020) and Keprate (2021), where they recorded higher B:C ratio under agroforestry systems as compared to sole agriculture cropping. Similar results were reported by Chavan and Dhillon (2019) who also recorded higher B:C ratio in agroforestry system as compared to sole cropping of sorghum-berseem and cowpea-wheat.

Chapter-5

SUMMAY AND CONCLUSION

The present investigation entitled **"Effects of organic manures on growth, yield and oil quality parameters of lemon grass under wild pomegranate based agroforestry system"** was conducted in the experimental farm at Pandah, Department of Silviculture and Agroforestry, College of Forestry, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh during the year 2021 to 2022. The study site is located in the mid-hill zone of Himachal Pradesh at $30^0$51'06'' N Latitude and 77^0 09' 49'' E Longitude, with an elevation of 1200 m above mean sea level. The experiment was carried out in wild pomegranate-based agroforestry model, having row to row distance as 4 m and tree to tree distance as 2 m where lemongrass was raised as intercrop between the tree rows and also in open field condition in a plot size of 4 m x 2 m, applied with 10 different treatments i.e., T_1: Recommended dose of nitrogen, T_2: FYM (on nitrogen equivalent ratio basis), T_3: Vermicompost (on nitrogen equivalent ratio basis), T_4: Goat manure (on nitrogen equivalent ratio basis), T_5: Jeevamrut @ 500 l/ha (5 %), T_6: FYM and RDN on 50:50 equivalence basis, T_7: Vermicompost and RDN on 50:50 equivalence basis, T_8: Goat manure and RDN on 50:50 equivalence basis, T_9: Jeevamrut and RDN on 50:50 equivalence basis, T_{10}: Control. The present study was conducted to evaluate the effect of organic manures on growth yield and quality parameters of lemongrass, on soil physico-chemical properties and economic feasibility of the wild pomegranate-lemongrass based agroforestry system. The results obtained from the study are summarized under the following heads:

5.1 EFFECT OF ORGANIC MANURES ON GROWTH, YIELD AND OIL QUALITY PARAMETERS OF LEMONGRASS

Growth, yield and quality parameters of lemongrass were studied under pomegranate-based agroforestry system as well as in open condition. The results of the present investigation showed that under different planting conditions, almost all growth, yield and quality parameters of lemongrass such as plant height (84.39 cm), number of tillers (58.75), plant spread (67.69 cm), fresh herb yield (18.21 Mg ha^{-1}), dry herb yield (6.90 Mg ha^{-1}), fresh leaves oil percentage (0.39 %), dry leaves oil percentage (1.04 %), oil yield (76.76 kg ha^{-1}), fresh leaves oil saponification (144.08 mg KOH/g), dry leaves oil saponification (142.82 mg

KOH/g), fresh leaves oil iodine value (116.99 $gI_2/100g$) and dry leaves oil iodine value (116.05 $gI_2/100g$) of lemongrass were significantly higher under open condition compared to pomegranate based agroforestry system exhibiting values as *viz*., plant height (81.95 cm), number of tillers (56.22), plant spread (63.42 cm), fresh herb yield (16.96 Mg ha^{-1}), dry herb yield (6.43 Mg ha^{-1}), fresh leaves oil percentage (0.38 %), dry leaves oil percentage (1.00 %), oil yield (60.31 kg ha^{-1}), fresh leaves oil saponification (143.08 mg KOH/g), dry leaves oil saponification (142.58 mg KOH/g), fresh leaves oil iodine value (116.39 $gI_2/100g$) and dry leaves oil iodine value (115.44 $gI_2/100g$) respectively. Pertaining to the planting conditions, low acid value i.e., 4.27 mg KOH/g) in fresh leaves oil and 4.46 mg KOH/g in dry leaves oil was recorded in open condition whereas higher acid value i.e., 4.31 mg KOH/g in fresh leaves oil and 4.49 mg KOH/g in dry leaves oil was recorded under AFS.

Among different treatments, T_8 (50 % goat manure + 50 % RDN) recorded maximum plant height (105.69 cm), number of tillers (76.58), plant spread (80.48 cm), fresh herb yield (21.09 Mg ha^{-1}), dry herb yield (7.99 Mg ha^{-1}), fresh leaves oil percentage (0.48 %), dry leaves oil percentage (1.27 %), oil yield (105.57 kg ha^{-1}), fresh leaves oil saponification (146.38 mg KOH/g), dry leaves oil saponification (145.18 mg KOH/g), fresh leaves oil iodine value (119.04 $gI_2/100g$) and dry leaves oil iodine value (118.07 $gI_2/100g$) of lemongrass, while minimum values of growth and quality parameters *viz*., plant height (64.99 cm), number of tillers (38.84), plant spread (52.44 cm), fresh herb yield (12.13 Mg ha^{-1}), dry herb yield (4.59 Mg ha^{-1}), fresh leaves oil percentage (0.28 %), dry leaves oil percentage (0.74 %), oil yield (36.05 kg ha^{-1}), fresh leaves oil saponification (139.71 mg KOH/g), dry leaves oil saponification (138.42 mg KOH/g), fresh leaves oil iodine value (112.84 $gI_2/100g$) and dry leaves oil iodine value (111.89 $gI_2/100g$) respectively were recorded in T_{10} i.e. control. Whereas, fresh leaves oil acid value (4.19 mg KOH/g) and dry leaves oil acid value (4.37 mg KOH/g) was lowest in T_8 (goat manure + RDN) while highest in T_{10} (control) i.e., 4.40 mg KOH/g in fresh leaves oil and 4.59 mg KOH/g in dry leaves oil.

The study revealed that Geranial (Citral-a) and Neral (Citral-b) were major compounds found in lemongrass essential oil. Citral a and Citral b content were highest in treatment T_8 (50 % goat manure +50 % RDN), 48.54 % and 33.61 % in open condition while 47.64 % and 28.77 %, respectively under wild pomegranate-based agroforestry system. Whereas, lowest Citral a and Citral b content was recorded in control, 17.93 % and 14.03 % in open condition and 17.27 % and 11.44 %, respectively under agroforestry system.

Among two years, minimum values of plant height (60.86 cm), number of tillers (51.98), plant spread (47.69 cm), fresh herb yield (12.85 Mg ha^{-1}), dry herb yield (4.87 Mg ha^{-1}), fresh leaves oil percentage (0.37 %), dry leaves oil percentage (0.97 %), oil yield per (52.85 kg ha^{-1}), fresh leaves oil saponification (143.73 mg KOH/g), dry leaves oil saponification (142.48 mg KOH/g), fresh leaves oil iodine value (116.38 gI_2/100g) and dry leaves oil iodine value (115.44 gI_2/100g) was recorded in 2021, respectively. In the year 2022 recorded maximum; plant height (105.48 cm), number of tillers (62.99), plant spread (83.42 cm), fresh herb yield (22.33 Mg ha^{-1}), dry herb yield (8.46 Mg ha^{-1}), fresh leaves oil percentage (0.41 %), dry leaves oil percentage (1.07 %), oil yield (93.22 kg ha^{-1}), fresh leaves oil saponification (144.15 mg KOH/g), dry leaves oil saponification (142.92 mg KOH/g), fresh leaves oil iodine value (117.00 gI_2/100g) and dry leaves oil iodine value (116.05 gI_2/100g) respectively. While, fresh leaves oil acid value (4.31 mg KOH/g) and dry leaves oil acid value (4.49 mg KOH/g) was higher in 2021 when compared to year 2022 i.e., 4.27 mg KOH/g in fresh leaves oil and 4.46 mg KOH/g in dry leaves oil.

5.2 EFFECT OF ORGANIC MANURES AND PLANTING CONDITIONS ON SOIL PHYSICO-CHEMICAL PROPERTIES

Physical and chemical properties of soil were found to be better in intercropping as compared to open (treeless area). Planting conditions and nutrient sources had significant effect on the soil properties. Under two planting conditions, higher soil electrical conductivity (0.295 dS m^{-1}), moisture content (9.21 %), available nitrogen (321.18 kg ha^{-1}), available phosphorus (52.52 kg ha^{-1}), available potassium (240.00 kg ha^{-1}) and organic carbon (0.69 %) was recorded under agroforestry system whereas, electrical conductivity (0.226 dS m^{-1}), moisture content (8.11 %), available nitrogen (308.22 kg ha^{-1}), available phosphorus (49.19 kg ha^{-1}), available potassium (234.48 kg ha^{-1}) and organic carbon (0.62 %) was low under open condition. Soil pH was low under agroforestry (6.89) as compared to control (6.95), this was due to the decomposition of leaf litter and release of humic acid under tree-based system, meanwhile soil bulk density was higher under open condition (1.08 g cm^{-3}) when compared to wild pomegranate-based agroforestry system (1.01 g cm^{-3}).

Among different treatments, soil pH (7.10) and bulk density (1.25 g cm^{-3}) was maximum under treatment T_{10} (control) whereas minimum values of pH (6.67) and bulk density (0.92 g cm^{-3}) were recorded under treatment T_4 (goat manure). However, soil moisture content was highest under the FYM treatment (10.05 %) and lowest under control

(7.66 %), meanwhile maximum electrical conductivity (0.307 dS m^{-1}), available nitrogen (362.13 kg ha^{-1}), available phosphorus (65.59 kg ha^{-1}), available potassium (285.50 kg ha^{-1}) and organic carbon (0.80 %) was recorded with the application of goat manure while electrical conductivity (0.231 dS m^{-1}), available nitrogen (260.33 kg ha^{-1}), available phosphorus (39.71 kg ha^{-1}), available potassium (205.49 kg ha^{-1}) and organic carbon (0.50 %) was minimum under control.

The soil properties were better in year 2022 compared to year 2021, showing positive impact of tree-based system and organic manures on soil. The present study revealed that agroforestry system and the organic manures improves the growth of plants by improving soil physico-chemical properties, enhancing microbial activity and increasing nutrient availability to plants helping in enhancing the yield of crops.

5.3 BIO-ECONOMICS OF THE SYSTEM

The results pertaining to the effect of planting conditions and organic manures on cost of cultivation, net returns, gross returns and benefit cost ratio for the cultivation of the lemongrass under wild pomegranate-based agroforestry revealed that growing of lemongrass under wild pomegranate is quite profitable. Comparing the two conditions, agroforestry system recorded maximum cost of cultivation (Rs 83931.37 ha^{-1}), gross returns (Rs 192729.85 ha^{-1}), net returns (Rs 108798.48 ha^{-1}) and benefit cost ratio (2.35) whereas minimum cost of cultivation (Rs 69583.33 ha^{-1}), gross returns (Rs 138165.27 ha^{-1}), net returns (Rs 68581.94 ha^{-1}) and benefit cost ratio (2.07) was recorded under open condition.

Among different treatments, T_3 (vermicompost) recorded maximum cost of cultivation (Rs 113454.39 ha^{-1}) and T_{10} (control) recorded minimum (Rs 49324.99 ha^{-1}). However, highest gross returns (Rs 224017.05 ha^{-1}) were recorded in treatment T_8 (50 % goat manure + 50 % RDN) while lowest (98871.34 ha^{-1}) in T_{10} (control). Treatment T_2 (FYM) recorded minimum net returns (Rs 43964.27 ha^{-1}) and benefit cost ratio (1.39) whereas maximum net returns (Rs 154573.06 ha^{-1}) and benefit cost ratio (3.20) was recorded in treatment T_8 (50 % goat manure + 50 % RDN), respectively.

Pertaining to the two years, higher gross returns (Rs 235769.36 ha^{-1}), net returns (Rs 158075.75 ha^{-1}) and benefit cost ratio (3.10) was recorded in year 2022 whereas lower gross returns (Rs 95125.77 ha^{-1}), net returns (Rs 19304.67 ha^{-1}) and benefit cost ratio (1.32) was recorded in year 2021.

CONCLUSION

- The study revealed that growth, yield and quality parameters of lemongrass increased significantly with the application of different organic manures under both planting conditions i.e., agroforestry system and open condition.
- The results showed that among different treatments, plant height, number of tillers, plant spread, fresh herb yield, dry herb yield, oil percentage, oil yield, saponification value, iodine value, Citral a and Citral b content was recorded maximum in T_8 (50 % goat manure + 50 % RDN), showing superiority of integrated nutrient management in increasing growth and quality parameters over sole application of organic manures or inorganic fertilizers.
- The physical and chemical properties of soil i.e., moisture (%), electrical conductivity, organic carbon, available nitrogen, phosphorus and potassium were higher in T_4 (goat manure) under wild pomegranate-based agroforestry system compared to sole cropping.
- Net returns and benefit cost ratio were recorded maximum in integrated nutrient treatment i.e., T_8 (50 % goat manure + 50 % RDN) under agroforestry system than in open condition.
- Conclusively, integration of inorganic fertilizers with organic manures in agroforestry system can be used with optimum rates to improve crop productivity on sustainable basis.

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Appendix I: Effect of planting conditions, treatments and number of harvestings on growth, yield and quality parameters of lemongrass

Effect of planting conditions, treatments and number of harvestings on plant height

Treatments	Agroforestry system (C1)						Open (C2)					
	2021			2022			2021			2022		
	Harvest 1	Harvest 2	Mean	Harvest 3	Harvest 4	Mean	Harvest 1	Harvest 2	Mean	Harvest 3	Harvest 4	Mean
T1	67.80	34.00	**50.90**	95.00	87.33	**91.17**	71.25	34.77	**53.01**	98.16	90.50	**94.33**
T2	74.67	36.57	**55.62**	101.33	93.00	**97.17**	79.00	36.56	**57.78**	104.27	96.13	**100.20**
T3	79.50	36.91	**58.21**	106.00	101.00	**103.50**	83.25	37.57	**60.41**	109.15	104.27	**106.71**
T4	83.73	40.83	**62.28**	107.33	102.33	**104.83**	87.35	41.46	**64.41**	110.66	105.15	**107.91**
T5	65.30	31.67	**48.49**	88.67	83.67	**86.17**	69.18	32.31	**50.75**	91.91	86.98	**89.45**
T6	95.00	41.83	**68.42**	118.33	106.00	**112.17**	96.44	42.55	**69.50**	121.39	108.80	**115.10**
T7	98.40	42.80	**70.60**	127.67	118.00	**122.84**	102.19	43.46	**72.83**	130.56	121.23	**125.90**
T8	108.10	45.87	**76.99**	135.33	129.67	**132.50**	109.25	46.49	**77.87**	138.17	132.67	**135.42**
T9	88.33	37.10	**62.72**	108.67	104.33	**106.50**	89.39	37.83	**63.61**	114.04	107.20	**110.62**
T10	60.87	30.83	**45.85**	83.33	80.83	**82.08**	63.29	30.58	**46.94**	86.55	83.61	**85.08**
Mean	**82.17**	**37.84**		**107.17**	**100.62**		**85.06**	**38.36**		**110.49**	**103.65**	

T_1:Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis),**T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis,**T_8**: Goat manure and RDN on 50:50 equivalence basis,**T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

Effect of planting conditions, treatments and number of harvestings on number of tillers per plant

Treatments	Agroforestry system (C1)						Open (C2)					
	2021			2022			2021			2022		
	Harvest 1	Harvest 2	Mean	Harvest 3	Harvest 4	Mean	Harvest 1	Harvest 2	Mean	Harvest 3	Harvest 4	Mean
T1	48.75	39.33	**44.04**	51.63	52.31	**51.97**	51.55	40.27	**45.91**	54.76	56.02	**55.39**
T2	52.52	40.90	**46.71**	56.96	57.12	**57.04**	55.34	40.32	**47.83**	61.34	60.17	**60.76**
T3	55.74	44.69	**50.22**	60.31	60.09	**60.20**	58.50	45.94	**52.22**	64.72	62.35	**63.54**
T4	57.29	49.23	**53.26**	60.68	64.33	**62.51**	60.11	49.98	**55.04**	66.37	68.72	**67.55**
T5	42.00	34.95	**38.47**	46.99	49.44	**48.22**	44.79	36.11	**40.45**	51.12	52.14	**51.63**
T6	67.41	54.80	**61.10**	72.20	71.94	**72.07**	70.25	54.88	**62.57**	75.94	74.70	**75.32**
T7	70.64	58.53	**64.58**	70.87	77.54	**74.21**	73.39	59.48	**66.43**	75.96	80.90	**78.43**
T8	74.99	64.05	**69.52**	79.82	82.63	**81.22**	77.76	63.67	**70.71**	84.28	85.49	**84.89**
T9	56.22	46.32	**51.27**	59.87	65.16	**62.52**	54.01	47.27	**50.64**	62.97	68.54	**65.76**
T10	35.74	31.26	**33.50**	40.26	43.38	**41.82**	38.15	32.16	**35.15**	43.42	46.33	**44.88**
Mean	**56.13**	**46.41**		**59.96**	**62.40**		**58.38**	**47.01**		**64.09**	**65.54**	

T_1:Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis),**T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis,**T_8**: Goat manure and RDN on 50:50 equivalence basis,**T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

Effect of planting conditions, treatments and number of harvestings on plant spread (cm)

Treatments	Agroforestry system (C1)						Open (C2)					
	2021			2022			2021			2022		
	Harvest 1	Harvest 2	Mean	Harvest 3	Harvest 4	Mean	Harvest 1	Harvest 2	Mean	Harvest 3	Harvest 4	Mean
T1	50.33	30.92	**40.63**	80.60	67.50	**74.05**	55.00	33.42	44.21	85.50	85.50	**54.53**
T2	55.17	33.22	**44.19**	85.00	72.30	**78.65**	59.67	35.72	47.69	90.22	90.22	**58.32**
T3	59.00	34.52	**46.76**	89.03	76.08	**82.56**	63.50	37.02	50.26	94.00	94.00	**61.19**
T4	62.32	36.20	**49.26**	92.33	79.25	**85.79**	66.67	38.70	52.68	97.27	97.27	**63.83**
T5	47.50	29.48	**38.49**	77.58	64.50	**71.04**	52.00	31.98	41.99	82.58	82.58	**52.14**
T6	63.33	38.47	**50.90**	93.28	80.17	**86.73**	67.67	40.97	54.32	98.08	98.08	**65.26**
T7	69.00	40.65	**54.83**	99.00	86.17	**92.58**	73.50	43.15	58.33	104.15	104.15	**69.78**
T8	74.38	42.92	**58.65**	104.30	91.68	**97.99**	79.00	45.42	62.21	109.62	109.62	**74.06**
T9	50.50	31.42	**40.96**	80.50	67.33	**73.92**	54.83	33.92	44.38	85.42	85.42	**54.64**
T10	42.42	27.12	**34.77**	71.83	59.50	**65.67**	47.00	29.62	38.31	77.50	77.50	**48.11**
Mean	**57.40**	**34.49**		**87.35**	**74.45**		**61.88**	**36.99**		**92.43**	**92.43**	**60.19**

$\mathbf{T_1}$:Recommended dose of nitrogen, $\mathbf{T_2}$: FYM (on nitrogen equivalent ratio basis), $\mathbf{T_3}$**:** Vermicompost (on nitrogen equivalent ratio basis),$\mathbf{T_4}$: Goat manure (on nitrogen equivalent ratio basis), $\mathbf{T_5}$: Jeevamrut @ 500 l/ha (5 %), $\mathbf{T_6}$: FYM and RDN on 50:50 equivalence basis, $\mathbf{T_7}$: Vermicompost and RDN on 50:50 equivalence basis,$\mathbf{T_8}$: Goat manure and RDN on 50:50 equivalence basis,$\mathbf{T_9}$: Jeevamrut and RDN on 50:50 equivalence basis, $\mathbf{T_{10}}$: Control

Effect of planting conditions, treatments and number of harvestings on fresh herb yield (Mg/ha)

Treatments	Agroforestry system (C1)						Open (C2)					
	2021			2022			2021			2022		
	Harvest 1	Harvest 2	Total	Harvest 3	Harvest 4	Total	Harvest 1	Harvest 2	Total	Harvest 3	Harvest 4	Total
T1	7.76	3.31	**11.07**	10.80	9.61	**20.41**	8.45	3.82	**12.27**	11.60	10.36	**21.96**
T2	8.22	3.46	**11.68**	11.21	9.86	**21.08**	8.90	3.97	**12.88**	11.93	10.62	**22.55**
T3	8.68	3.62	**12.30**	11.34	10.33	**21.67**	9.37	4.13	**13.49**	12.10	11.08	**23.18**
T4	9.11	4.03	**13.14**	12.06	10.66	**22.73**	9.80	4.54	**14.34**	12.74	11.42	**24.16**
T5	7.27	2.68	**9.95**	10.38	9.10	**19.48**	7.96	3.19	**11.15**	11.36	9.85	**21.21**
T6	9.38	4.26	**13.64**	12.84	10.83	**23.67**	10.07	4.77	**14.84**	13.17	11.58	**24.76**
T7	9.90	4.45	**14.35**	13.34	11.47	**24.81**	10.58	4.96	**15.55**	13.67	12.23	**25.90**
T8	10.38	4.74	**15.13**	13.97	11.90	**25.87**	11.07	5.25	**16.32**	14.39	12.66	**27.05**
T9	8.95	3.56	**12.51**	12.23	10.50	**22.73**	9.64	4.07	**13.71**	12.25	11.25	**23.50**
T10	6.36	2.48	**8.84**	8.13	6.11	**14.23**	6.84	2.99	**9.83**	8.75	6.86	**15.61**
Mean	**8.60**	**3.66**		**11.63**	**10.04**		**9.27**	**4.17**		**12.20**	**10.79**	

T_1:Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis),**T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis,**T_8**: Goat manure and RDN on 50:50 equivalence basis,**T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

Effect of planting conditions, treatments and number of harvestings on dry yield (Mg/ha)

Treatments	Agroforestry system (C1)						Open (C2)					
	2021			2022			2021			2022		
	Harvest 1	Harvest 2	Total	Harvest 3	Harvest 4	Total	Harvest 1	Harvest 2	Total	Harvest 3	Harvest 4	Total
T1	2.94	1.25	**4.19**	4.09	3.64	**7.73**	3.20	1.45	**4.65**	4.39	3.92	**8.32**
T2	3.11	1.31	**4.42**	4.25	3.74	**7.98**	3.37	1.50	**4.88**	4.52	4.02	**8.54**
T3	3.29	1.37	**4.66**	4.30	3.91	**8.21**	3.55	1.56	**5.11**	4.58	4.20	**8.78**
T4	3.45	1.53	**4.98**	4.57	4.04	**8.61**	3.71	1.72	**5.43**	4.83	4.32	**9.15**
T5	2.75	1.02	**3.77**	3.93	3.45	**7.38**	3.01	1.21	**4.22**	4.30	3.73	**8.04**
T6	3.55	1.61	**5.17**	4.86	4.10	**8.97**	3.81	1.81	**5.62**	4.99	4.39	**9.38**
T7	3.75	1.69	**5.44**	5.05	4.35	**9.40**	4.01	1.88	**5.89**	5.18	4.63	**9.81**
T8	3.93	1.80	**5.73**	5.29	4.51	**9.80**	4.19	1.99	**6.18**	5.45	4.79	**10.25**
T9	3.39	1.35	**4.74**	4.63	3.98	**8.61**	3.65	1.54	**5.19**	4.64	4.26	**8.90**
T10	2.41	0.94	**3.35**	3.08	2.31	**5.39**	2.59	1.13	**3.72**	3.31	2.60	**5.91**
Mean	**3.26**	**1.39**		**4.41**	**3.80**		**3.51**	**1.58**		**4.62**	**4.09**	

T_1:Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis),**T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis,**T_8**: Goat manure and RDN on 50:50 equivalence basis,**T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

Effect of planting conditions, treatments and number of harvestings on fresh leaves oil percentage (%)

Treatments	Agroforestry system (C1)						Open (C2)					
	2021			2022			2021			2022		
	Harvest 1	Harvest 2	Mean	Harvest 3	Harvest 4	Mean	Harvest 1	Harvest 2	Mean	Harvest 3	Harvest 4	Mean
T1	0.42	0.24	**0.33**	0.36	0.33	**0.35**	0.43	0.23	**0.33**	0.38	0.35	**0.36**
T2	0.43	0.25	**0.34**	0.38	0.37	**0.37**	0.43	0.25	**0.34**	0.41	0.38	**0.39**
T3	0.46	0.27	**0.36**	0.42	0.40	**0.41**	0.47	0.28	**0.37**	0.43	0.41	**0.42**
T4	0.48	0.29	**0.39**	0.45	0.41	**0.43**	0.50	0.31	**0.40**	0.46	0.44	**0.45**
T5	0.39	0.22	**0.31**	0.35	0.32	**0.34**	0.42	0.21	**0.32**	0.36	0.33	**0.35**
T6	0.49	0.28	**0.39**	0.46	0.42	**0.44**	0.48	0.32	**0.40**	0.48	0.43	**0.46**
T7	0.53	0.32	**0.42**	0.48	0.46	**0.47**	0.54	0.34	**0.44**	0.51	0.46	**0.49**
T8	0.55	0.35	**0.45**	0.51	0.48	**0.50**	0.57	0.35	**0.46**	0.52	0.50	**0.51**
T9	0.48	0.26	**0.37**	0.44	0.39	**0.41**	0.50	0.28	**0.39**	0.45	0.42	**0.44**
T10	0.32	0.21	**0.27**	0.30	0.29	**0.29**	0.34	0.22	**0.28**	0.32	0.28	**0.30**
Mean	**0.45**	**0.27**		**0.41**	**0.39**		**0.47**	**0.28**		**0.43**	**0.40**	

T_1:Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis),**T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis,**T_8**: Goat manure and RDN on 50:50 equivalence basis,**T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

Effect of planting conditions, treatments and number of harvestings on dry leaves oil percentage (%)

Treatments	Agroforestry system (C1)						Open (C2)					
	2021			2022			2021			2022		
	Harvest 1	Harvest 2	Mean	Harvest 3	Harvest 4	Mean	Harvest 1	Harvest 2	Mean	Harvest 3	Harvest 4	Mean
T1	1.10	0.62	**0.86**	0.99	0.87	**0.93**	1.13	0.61	**0.87**	1.00	0.92	**0.96**
T2	1.10	0.65	**0.87**	1.05	1.00	**1.02**	1.18	0.63	**0.91**	1.05	1.01	**1.03**
T3	1.23	0.68	**0.96**	1.08	1.03	**1.05**	1.19	0.73	**0.96**	1.11	1.09	**1.10**
T4	1.26	0.78	**1.02**	1.16	1.07	**1.11**	1.26	0.78	**1.02**	1.19	1.17	**1.18**
T5	1.01	0.58	**0.80**	0.94	0.82	**0.88**	1.08	0.57	**0.82**	0.97	0.87	**0.92**
T6	1.31	0.72	**1.01**	1.19	1.08	**1.14**	1.27	0.85	**1.06**	1.28	1.14	**1.21**
T7	1.41	0.86	**1.14**	1.27	1.18	**1.23**	1.43	0.89	**1.16**	1.37	1.19	**1.28**
T8	1.43	0.95	**1.19**	1.32	1.30	**1.31**	1.48	0.95	**1.22**	1.40	1.34	**1.37**
T9	1.26	0.72	**0.99**	1.13	1.01	**1.07**	1.30	0.75	**1.02**	1.21	1.11	**1.16**
T10	0.91	0.54	**0.73**	0.77	0.77	**0.77**	0.86	0.57	**0.71**	0.76	0.74	**0.75**
Mean	**1.20**	**0.71**		**1.09**	**1.01**		**1.22**	**0.73**		**1.13**	**1.06**	

$\mathbf{T_1}$:Recommended dose of nitrogen, $\mathbf{T_2}$: FYM (on nitrogen equivalent ratio basis), $\mathbf{T_3}$**:** Vermicompost (on nitrogen equivalent ratio basis),$\mathbf{T_4}$: Goat manure (on nitrogen equivalent ratio basis), $\mathbf{T_5}$: Jeevamrut @ 500 l/ha (5 %), $\mathbf{T_6}$: FYM and RDN on 50:50 equivalence basis, $\mathbf{T_7}$: Vermicompost and RDN on 50:50 equivalence basis,$\mathbf{T_8}$: Goat manure and RDN on 50:50 equivalence basis,$\mathbf{T_9}$: Jeevamrut and RDN on 50:50 equivalence basis, $\mathbf{T_{10}}$: Control

Effect of planting conditions, treatments and number of harvestings on oil yield (Kg/ha)

Treatments	Agroforestry system (C1)						Open (C2)					
	2021			2022			2021			2022		
	Harvest 1	Harvest 2	Total	Harvest 3	Harvest 4	Total	Harvest 1	Harvest 2	Total	Harvest 3	Harvest 4	Total
T1	32.35	7.83	**40.18**	39.26	31.38	**70.64**	36.06	8.91	**44.96**	43.68	36.27	**79.95**
T2	35.02	8.55	**43.57**	42.58	36.16	**78.74**	37.96	9.93	**47.89**	48.53	40.34	**88.87**
T3	39.66	9.65	**49.31**	47.70	40.98	**88.68**	43.70	11.55	**55.26**	51.62	45.80	**97.42**
T4	43.38	11.82	**55.20**	54.36	44.08	**98.45**	48.72	13.91	**62.63**	58.19	50.61	**108.80**
T5	28.11	5.99	**34.10**	36.68	29.10	**65.78**	33.40	6.80	**40.20**	41.29	32.84	**74.13**
T6	46.30	11.92	**58.23**	58.69	45.13	**103.81**	48.02	15.42	**63.44**	63.25	50.19	**113.45**
T7	52.44	14.09	**66.53**	64.56	52.39	**116.96**	57.15	16.88	**74.03**	70.18	55.83	**126.01**
T8	57.12	16.75	**73.87**	70.91	57.59	**128.50**	62.73	18.55	**81.28**	75.32	63.33	**138.65**
T9	42.67	9.26	**51.93**	53.65	40.59	**94.24**	47.91	11.26	**59.17**	55.50	46.87	**102.38**
T10	20.55	5.12	**25.66**	24.17	17.69	**41.86**	23.06	6.46	**29.52**	27.71	19.43	**47.14**
Mean	**39.76**	**10.10**		**49.26**	**39.51**		**43.87**	**11.97**		**53.53**	**44.15**	

$\mathbf{T_1}$:Recommended dose of nitrogen, $\mathbf{T_2}$: FYM (on nitrogen equivalent ratio basis), $\mathbf{T_3}$**:** Vermicompost (on nitrogen equivalent ratio basis),$\mathbf{T_4}$: Goat manure (on nitrogen equivalent ratio basis), $\mathbf{T_5}$: Jeevamrut @ 500 l/ha (5 %), $\mathbf{T_6}$: FYM and RDN on 50:50 equivalence basis, $\mathbf{T_7}$: Vermicompost and RDN on 50:50 equivalence basis,$\mathbf{T_8}$: Goat manure and RDN on 50:50 equivalence basis,$\mathbf{T_9}$: Jeevamrut and RDN on 50:50 equivalence basis, $\mathbf{T_{10}}$: Control

Effect of planting conditions, treatments and number of harvestings on fresh leaves oil acid value (mg KOH/g)

Treatments	Agroforestry system (C1)						Open (C2)					
	2021			2022			2021			2022		
	Harvest 1	Harvest 2	Mean	Harvest 3	Harvest 4	Mean	Harvest 1	Harvest 2	Mean	Harvest 3	Harvest 4	Mean
T1	4.44	4.39	**4.42**	4.35	4.42	**4.38**	4.43	4.35	**4.39**	4.31	4.37	**4.34**
T2	4.35	4.30	**4.33**	4.26	4.33	**4.30**	4.33	4.26	**4.30**	4.22	4.28	**4.25**
T3	4.33	4.29	**4.31**	4.25	4.32	**4.28**	4.32	4.25	**4.28**	4.21	4.26	**4.24**
T4	4.33	4.26	**4.29**	4.22	4.29	**4.26**	4.31	4.22	**4.27**	4.18	4.25	**4.21**
T5	4.41	4.36	**4.39**	4.32	4.39	**4.36**	4.39	4.32	**4.36**	4.28	4.34	**4.31**
T6	4.30	4.26	**4.28**	4.22	4.29	**4.26**	4.28	4.23	**4.25**	4.19	4.24	**4.21**
T7	4.28	4.23	**4.25**	4.19	4.26	**4.22**	4.26	4.19	**4.22**	4.15	4.21	**4.18**
T8	4.24	4.20	**4.22**	4.16	4.23	**4.19**	4.23	4.16	**4.19**	4.12	4.17	**4.15**
T9	4.32	4.27	**4.29**	4.23	4.30	**4.26**	4.30	4.23	**4.26**	4.19	4.25	**4.22**
T10	4.46	4.40	**4.43**	4.37	4.44	**4.41**	4.45	4.38	**4.42**	4.32	4.39	**4.35**
Mean	**4.35**	**4.30**		**4.26**	**4.33**		**4.33**	**4.26**		**4.22**	**4.28**	

$\mathbf{T_1}$:Recommended dose of nitrogen, $\mathbf{T_2}$: FYM (on nitrogen equivalent ratio basis), $\mathbf{T_3}$**:** Vermicompost (on nitrogen equivalent ratio basis),$\mathbf{T_4}$: Goat manure (on nitrogen equivalent ratio basis), $\mathbf{T_5}$: Jeevamrut @ 500 l/ha (5 %), $\mathbf{T_6}$: FYM and RDN on 50:50 equivalence basis, $\mathbf{T_7}$: Vermicompost and RDN on 50:50 equivalence basis,$\mathbf{T_8}$: Goat manure and RDN on 50:50 equivalence basis,$\mathbf{T_9}$: Jeevamrut and RDN on 50:50 equivalence basis, $\mathbf{T_{10}}$: Control

Effect of planting conditions, treatments and number of harvestings on dry leaves oil acid value (mg KOH/g)

Treatments	Agroforestry system (C1)						Open (C2)					
	2021			2022			2021			2022		
	Harvest 1	Harvest 2	Mean	Harvest 3	Harvest 4	Mean	Harvest 1	Harvest 2	Mean	Harvest 3	Harvest 4	Mean
T2	4.53	4.48	**4.51**	4.44	4.52	**4.48**	4.51	4.44	**4.48**	4.40	4.49	**4.45**
T3	4.51	4.47	**4.49**	4.43	4.51	**4.47**	4.50	4.43	**4.46**	4.39	4.48	**4.44**
T4	4.51	4.44	**4.47**	4.40	4.48	**4.44**	4.49	4.40	**4.45**	4.36	4.45	**4.41**
T5	4.59	4.54	**4.57**	4.50	4.58	**4.54**	4.57	4.50	**4.54**	4.46	4.55	**4.51**
T6	4.48	4.44	**4.46**	4.40	4.48	**4.44**	4.46	4.41	**4.43**	4.37	4.46	**4.41**
T7	4.46	4.41	**4.43**	4.37	4.45	**4.41**	4.44	4.37	**4.40**	4.33	4.42	**4.38**
T8	4.42	4.38	**4.40**	4.34	4.42	**4.38**	4.41	4.34	**4.37**	4.30	4.39	**4.35**
T9	4.50	4.45	**4.47**	4.41	4.49	**4.45**	4.48	4.41	**4.44**	4.37	4.46	**4.42**
T10	4.64	4.58	**4.61**	4.55	4.62	**4.58**	4.63	4.56	**4.60**	4.51	4.60	**4.56**
Mean	**4.53**	**4.48**		**4.44**	**4.51**		**4.51**	**4.44**		**4.40**	**4.49**	

T_1:Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis),**T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis,**T_8**: Goat manure and RDN on 50:50 equivalence basis,**T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

Effect of planting conditions, treatments and number of harvestings on fresh leaves oil saponification value (mg KOH/g)

Treatments	Agroforestry system (C1)						Open (C2)					
	2021			2022			2021			2022		
	Harvest 1	Harvest 2	Mean	Harvest 3	Harvest 4	Mean	Harvest 1	Harvest 2	Mean	Harvest 3	Harvest 4	Mean
T1	141.16	141.41	**141.28**	141.98	141.17	**141.57**	141.35	141.71	**141.53**	142.12	141.92	**142.02**
T2	143.16	143.59	**143.38**	143.98	143.30	**143.64**	143.38	143.63	**143.51**	144.14	143.95	**144.04**
T3	143.35	143.75	**143.55**	145.01	143.45	**144.23**	143.55	143.79	**143.67**	144.32	144.11	**144.22**
T4	144.20	144.44	**144.32**	144.32	144.20	**144.26**	144.49	144.73	**144.61**	145.23	145.03	**145.13**
T5	143.51	143.41	**143.46**	144.16	143.29	**143.73**	142.98	143.23	**143.11**	144.12	143.55	**143.83**
T6	145.28	145.52	**145.40**	146.09	145.28	**145.69**	145.49	145.74	**145.62**	146.23	146.03	**146.13**
T7	145.80	146.05	**145.93**	146.62	145.81	**146.22**	145.92	146.17	**146.04**	146.64	146.48	**146.56**
T8	145.89	146.13	**146.01**	146.70	145.89	**146.30**	146.21	146.46	**146.33**	146.97	146.77	**146.87**
T9	143.75	144.00	**143.87**	144.57	143.76	**144.16**	143.94	144.19	**144.06**	144.65	144.49	**144.57**
T10	139.25	139.50	**139.37**	140.07	139.26	**139.66**	139.45	139.70	**139.58**	140.44	140.02	**140.23**
Mean	**143.53**	**143.78**		**144.35**	**143.54**		**143.68**	**143.94**		**144.49**	**144.24**	

T_1:Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis),**T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis,**T_8**: Goat manure and RDN on 50:50 equivalence basis,**T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

Effect of planting conditions, treatments and number of harvestings on dry leaves oil saponification value (mg KOH/g)

Treatments	Agroforestry system (C1)						Open (C2)					
	2021			2022			2021			2022		
	Harvest 1	Harvest 2	Mean	Harvest 3	Harvest 4	Mean	Harvest 1	Harvest 2	Mean	Harvest 3	Harvest 4	Mean
T1	139.92	140.16	**140.04**	140.73	139.99	**140.36**	140.12	140.46	**140.29**	140.86	140.64	**140.75**
T2	141.92	142.35	**142.13**	142.73	142.20	**142.47**	142.11	142.24	**142.18**	142.78	142.68	**142.73**
T3	142.10	142.51	**142.31**	143.77	142.37	**143.07**	142.31	142.54	**142.43**	143.08	142.87	**142.97**
T4	142.95	143.20	**143.08**	143.08	143.07	**143.07**	143.29	143.44	**143.36**	144.03	143.81	**143.92**
T5	142.26	142.16	**142.21**	142.92	142.01	**142.47**	141.74	141.96	**141.85**	142.86	142.19	**142.53**
T6	144.03	144.28	**144.16**	144.85	144.13	**144.49**	144.17	144.49	**144.33**	144.90	144.77	**144.84**
T7	144.56	144.81	**144.68**	145.38	144.66	**145.02**	144.66	144.94	**144.80**	145.36	145.17	**145.26**
T8	144.64	144.89	**144.77**	145.46	144.74	**145.10**	145.01	145.30	**145.16**	145.76	145.63	**145.70**
T9	142.51	142.75	**142.63**	143.32	142.62	**142.97**	142.70	142.94	**142.82**	143.39	143.25	**143.32**
T10	138.01	138.25	**138.13**	138.82	137.89	**138.36**	138.12	138.42	**138.27**	139.16	138.71	**138.94**
Mean	**142.29**	**142.54**		**143.11**	**142.37**		**142.42**	**142.67**		**143.22**	**142.97**	

T_1:Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis),**T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis,**T_8**: Goat manure and RDN on 50:50 equivalence basis,**T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

Effect of planting conditions, treatments and number of harvestings on fresh leaves oil iodine value ($gI_2/100g$)

Treatments	Agroforestry system (C1)						Open (C2)					
	2021			2022			2021			2022		
	Harvest 1	Harvest 2	Mean	Harvest 3	Harvest 4	Mean	Harvest 1	Harvest 2	Mean	Harvest 3	Harvest 4	Mean
T1	114.12	114.39	**114.26**	114.76	114.99	**114.88**	114.77	115.06	**114.91**	115.43	115.66	**115.55**
T2	115.80	116.07	**115.94**	116.44	116.67	**116.56**	116.08	116.38	**116.23**	116.69	116.98	**116.83**
T3	115.83	116.10	**115.97**	116.47	116.70	**116.59**	116.59	116.88	**116.74**	117.25	117.48	**117.36**
T4	116.50	116.77	**116.64**	117.14	117.37	**117.26**	117.18	117.47	**117.32**	117.85	118.07	**117.96**
T5	114.62	114.89	**114.76**	115.26	115.49	**115.38**	115.21	115.50	**115.35**	115.83	116.10	**115.96**
T6	117.53	117.80	**117.67**	118.17	118.40	**118.29**	118.02	118.34	**118.18**	118.67	118.94	**118.80**
T7	117.87	118.14	**118.01**	118.51	118.74	**118.63**	118.50	118.80	**118.65**	119.15	119.40	**119.27**
T8	118.22	118.49	**118.36**	118.86	119.09	**118.98**	118.88	119.21	**119.04**	119.72	119.81	**119.76**
T9	116.80	117.07	**116.94**	117.44	117.67	**117.56**	117.37	117.66	**117.52**	117.98	118.26	**118.12**
T10	112.11	112.38	**112.25**	112.75	112.98	**112.87**	112.64	112.94	**112.79**	113.35	113.54	**113.44**
Mean	**115.94**	**116.21**		**116.58**	**116.81**		**116.52**	**116.82**		**117.19**	**117.42**	

T_1:Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis),**T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis,**T_8**: Goat manure and RDN on 50:50 equivalence basis,**T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

Effect of planting conditions, treatments and number of harvestings on dry leaves oil iodine value ($gI_2/100g$)

Treatments	Agroforestry system (C1)						Open (C2)					
	2021			2022			2021			2022		
	Harvest 1	Harvest 2	Mean	Harvest 3	Harvest 4	Mean	Harvest 1	Harvest 2	Mean	Harvest 3	Harvest 4	Mean
T1	113.18	113.45	**113.32**	113.82	114.03	**113.93**	113.84	114.11	**113.98**	114.49	114.70	**114.60**
T2	114.86	115.13	**115.00**	115.50	115.71	**115.61**	115.16	115.42	**115.29**	115.81	116.02	**115.91**
T3	114.89	115.16	**115.03**	115.53	115.74	**115.64**	115.67	115.93	**115.80**	116.31	116.52	**116.42**
T4	115.56	115.83	**115.70**	116.20	116.41	**116.31**	116.25	116.52	**116.39**	116.90	117.11	**117.01**
T5	113.68	113.95	**113.82**	114.32	114.53	**114.43**	114.28	114.55	**114.42**	114.93	115.14	**115.04**
T6	116.59	116.86	**116.73**	117.23	117.44	**117.34**	117.09	117.38	**117.24**	117.77	117.98	**117.87**
T7	116.93	117.20	**117.07**	117.57	117.78	**117.68**	117.58	117.84	**117.71**	118.23	118.44	**118.33**
T8	117.28	117.55	**117.42**	117.92	118.13	**118.03**	117.96	118.25	**118.11**	118.64	118.85	**118.74**
T9	115.86	116.13	**116.00**	116.50	116.71	**116.61**	116.45	116.71	**116.58**	117.09	117.30	**117.20**
T10	111.17	111.44	**111.31**	111.81	112.02	**111.92**	111.71	111.98	**111.85**	112.37	112.58	**112.47**
Mean	**115.00**	**115.27**		**115.64**	**115.85**		**115.60**	**115.87**		**116.25**	**116.46**	

T_1:Recommended dose of nitrogen, **T_2**: FYM (on nitrogen equivalent ratio basis), **T_3:** Vermicompost (on nitrogen equivalent ratio basis),**T_4**: Goat manure (on nitrogen equivalent ratio basis), **T_5**: Jeevamrut @ 500 l/ha (5 %), **T_6**: FYM and RDN on 50:50 equivalence basis, **T_7**: Vermicompost and RDN on 50:50 equivalence basis,**T_8**: Goat manure and RDN on 50:50 equivalence basis,**T_9**: Jeevamrut and RDN on 50:50 equivalence basis, **T_{10}**: Control

Appendix II: Analysis of variance for growth, yield and quality parameters of lemongrass under different treatments, year and planting conditions

Plant height					
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Significance**
Replication	2	20.270			
Treatment T	9	17904.623	1989.403	342.868	0.00000
Year Y	1	59740.360	59740.360	10296.086	0.00000
Interaction T X Y	9	987.006	109.667	18.901	0.00000
Condition C	1	179.177	179.177	30.881	0.00000
Interaction T X C	9	2.567	0.285	0.049	0.99998
Interaction Y X C	1	15.993	15.993	2.756	0.10088
Interaction T X Y X C	9	4.382	0.487	0.084	0.99979
Error	78	452.575	5.802		
Total	**119**	**79306.953**			
Number of tillers					
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Significance**
Replication	2	19.584			
Treatment T	9	15040.382	1671.154	779.120	0.00000
Year Y	1	3638.531	3638.531	1696.345	0.00000
Interaction T X Y	9	57.982	6.442	3.004	0.00398
Condition C	1	192.565	192.565	89.777	0.00000
Interaction T X C	9	7.992	0.888	0.414	0.92403
Interaction Y X C	1	36.475	36.475	17.005	0.00009
Interaction T X Y X C	9	5.099	0.567	0.264	0.98232
Error	78	167.304	2.145		
Total	**119**	**19165.913**			
Plant spread					
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Significance**
Replication	2	60.436			
Treatment T	9	8392.005	932.445	193.972	0.00000
Year Y	1	38290.240	38290.240	7965.335	0.00000
Interaction T X Y	9	176.414	19.602	4.078	0.00026
Condition C	1	546.367	546.367	113.658	0.00000
Interaction T X C	9	0.044	0.005	0.001	0.00000
Interaction Y X C	1	17.792	17.792	3.701	0.05802
Interaction T X Y X C	9	0.204	0.023	0.005	1.00000
Error	78	374.955	4.807		
Total	**119**	**47858.369**			

Fresh herb yield					
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Significance**
Replication	2	2.365			
Treatment T	9	701.706	77.967	403.153	0.00000
Year Y	1	2719.361	2719.361	14061.250	0.00000
Interaction T X Y	9	55.765	6.196	32.039	0.00000
Condition C	1	49.871	49.871	257.871	0.00000
Interaction T X C	9	1.196	0.133	0.687	0.71835
Interaction Y X C	1	0.017	0.017	0.086	0.76949
Interaction T X Y X C	9	0.968	0.108	0.556	0.82858
Error	78	15.085	0.193		
Total	**119**	**3546.332**			
Dry herb yield					
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Significance**
Replication	2	0.464			
Treatment T	9	101.342	11.260	392.401	0.00000
Year Y	1	386.729	386.729	13476.928	0.00000
Interaction T X Y	9	7.855	0.873	30.415	0.00000
Condition C	1	6.693	6.693	233.242	0.00000
Interaction T X C	9	0.080	0.009	0.310	0.96955
Interaction Y X C	1	0.022	0.022	0.763	0.38502
Interaction T X Y X C	9	0.086	0.010	0.333	0.96134
Error	78	2.238	0.029		
Total	**119**	**505.509**			
Fresh leaves oil percentage					
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Significance**
Replication	2	0.002			
Treatment T	9	0.387	0.043	258.108	0.00000
Year Y	1	0.052	0.052	312.781	0.00000
Interaction T X Y	9	0.003	0.000	1.874	0.06817
Condition C	1	0.006	0.006	35.369	0.00000
Interaction T X C	9	0.000	0.000	0.251	0.98514
Interaction Y X C	1	0.000	0.000	1.214	0.27384
Interaction T X Y X C	9	0.000	0.000	0.243	0.98681
Error	78	0.013	0.000		
Total	**119**	**0.463**			

Dry leaves oil percentage					
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Significance**
Replication	2	0.002			
Treatment T	9	2.743	0.305	569.015	0.00000
Year Y	1	0.321	0.321	599.998	0.00000
Interaction T X Y	9	0.026	0.003	5.494	0.00001
Condition C	1	0.037	0.037	69.313	0.00000
Interaction T X C	9	0.021	0.002	4.395	0.00012
Interaction Y X C	1	0.009	0.009	16.487	0.00012
Interaction T X Y X C	9	0.016	0.002	3.398	0.00145
Error	78	0.042	0.001		
Total	**119**	**3.219**			
Oil yield					
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Significance**
Replication	2	210.425			
Treatment T	9	45782.775	5086.975	386.882	0.00000
Year Y	1	48904.496	48904.496	3719.351	0.00000
Interaction T X Y	9	3338.708	370.968	28.213	0.00000
Condition C	1	1663.436	1663.436	126.510	0.00000
Interaction T X C	9	39.455	4.384	0.333	0.96126
Interaction Y X C	1	64.686	64.686	4.920	0.02946
Interaction T X Y X C	9	16.361	1.818	0.138	0.99843
Error	78	1025.596	13.149		
Total	**119**	**101045.938**			
Fresh leaves oil acid value					
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Significance**
Replication	2	0.001			
Treatment T	9	0.527	0.059	293.718	0.00000
Year Y	1	0.034	0.034	172.036	0.00000
Interaction T X Y	9	0.001	0.000	0.289	0.97596
Condition C	1	0.028	0.028	142.967	0.00000
Interaction T X C	9	0.000	0.000	0.218	0.99112
Interaction Y X C	1	0.000	0.000	1.687	0.19777
Interaction T X Y X C	9	0.001	0.000	0.385	0.93911
Error	78	0.016	0.000		
Total	**119**	**0.608**			

Dry leaves oil acid value					
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Significance**
Replication	2	0.001			
Treatment T	9	0.519	0.058	231.517	0.00000
Year Y	1	0.023	0.023	92.254	0.00000
Interaction T X Y	9	0.000	0.000	0.018	1.00000
Condition C	1	0.024	0.024	95.597	0.00000
Interaction T X C	9	0.000	0.000	0.064	0.00000
Interaction Y X C	1	0.001	0.001	2.179	0.00000
Interaction T X Y X C	9	0.001	0.000	0.309	0.96975
Error	78	0.019	0.000		
Total	**119**	**0.585**			
Fresh leaves oil saponification value					
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Significance**
Replication	2	0.736			
Treatment T	9	459.007	51.001	2185.071	0.00000
Year Y	1	6.199	6.199	265.583	0.00000
Interaction T X Y	9	0.611	0.068	2.909	0.00000
Condition C	1	2.962	2.962	126.918	0.00000
Interaction T X C	9	0.444	0.049	2.112	0.03819
Interaction Y X C	1	0.023	0.023	0.973	0.00000
Interaction T X Y X C	9	0.824	0.092	3.921	0.00038
Error	78	1.821	0.023		
Total	**119**	**471.358**			
Dry leaves oil saponification value					
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Significance**
Replication	2	0.929			
Treatment T	9	464.845	51.649	698.750	0.00000
Year Y	1	4.553	4.553	61.599	0.00000
Interaction T X Y	9	1.331	0.148	2.000	0.05025
Condition C	1	0.984	0.984	13.317	0.00047
Interaction T X C	9	2.077	0.231	3.121	0.00294
Interaction Y X C	1	1.491	1.491	20.176	0.00002
Interaction T X Y X C	9	0.746	0.083	1.121	0.00000
Error	78	5.766	0.074		
Total	**119**	**479.372**			

Fresh leaves oil iodine value					
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Significance**
Replication	2	0.339			
Treatment T	9	391.337	43.482	4775.114	0.00000
Year Y	1	11.579	11.579	1271.577	0.00000
Interaction T X Y	9	0.242	0.027	2.956	0.00449
Condition C	1	10.350	10.350	1136.663	0.00000
Interaction T X C	9	1.047	0.116	12.771	0.00000
Interaction Y X C	1	0.286	0.286	31.396	0.00000
Interaction T X Y X C	9	0.312	0.035	3.811	0.00000
Error	78	0.710	0.009		
Total	**119**	**414.900**			
Dry leaves oil iodine value					
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Significance**
Replication	2	0.247			
Treatment T	9	391.836	43.537	23050.134	0.00000
Year Y	1	11.527	11.527	6102.829	0.00000
Interaction T X Y	9	0.071	0.008	4.151	0.00000
Condition C	1	11.027	11.027	5838.223	0.00000
Interaction T X C	9	0.326	0.036	19.163	0.00000
Interaction Y X C	1	0.224	0.224	118.627	0.88000
Interaction T X Y X C	9	0.234	0.026	13.744	0.00000
Error	78	0.147	0.002		
Total	**119**	**415.050**			

Appendix III: Analysis of variance for soil physico-chemical properties under different treatments, year and planting conditions

Soil pH					
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Significance**
Replication	2	0.002			
Treatment T	9	1.794	0.199	390.135	0.00000
Year Y	1	0.401	0.401	784.803	0.00000
Interaction T X Y	9	0.180	0.020	39.224	0.00000
Condition C	1	0.099	0.099	193.502	0.00000
Interaction T X C	9	0.048	0.005	10.349	0.00000
Interaction Y X C	1	0.073	0.073	142.182	0.00000
Interaction T X Y X C	9	0.087	0.010	18.943	0.00000
Error	78	0.040	0.001		
Total	**119**	**2.724**			
Electrical conductivity					
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Significance**
Replication	2	0.000			
Treatment T	9	0.062	0.007	1137.969	0.00000
Year Y	1	0.002	0.002	338.492	0.00000
Interaction T X Y	9	0.000	0.000	7.713	0.00000
Condition C	1	0.145	0.145	23931.117	0.00000
Interaction T X C	9	0.001	0.000	13.773	0.00000
Interaction Y X C	1	0.000	0.000	16.465	0.00012
Interaction T X Y X C	9	0.000	0.000	6.629	0.00000
Error	78	0.000	0.000		
Total	**119**	**0.211**			
Bulk density					
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Significance**
Replication	2	0.000			
Treatment T	9	1.391	0.155	319.827	0.00000
Year Y	1	0.028	0.028	58.928	0.00000
Interaction T X Y	9	0.003	0.000	0.779	0.63646
Condition C	1	0.152	0.152	314.384	0.00000
Interaction T X C	9	0.026	0.003	5.954	0.00000
Interaction Y X C	1	0.001	0.001	2.435	0.12270
Interaction T X Y X C	9	0.005	0.001	1.123	0.35699
Error	78	0.038	0.000		
Total	**119**	**1.644**			

Moisture content					
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Significance**
Replication	2	0.007			
Treatment T	9	54.947	6.105	5938.476	0.00000
Year Y	1	14.544	14.544	14146.377	0.00000
Interaction T X Y	9	0.527	0.059	56.960	0.00000
Condition C	1	36.337	36.337	35344.602	0.00000
Interaction T X C	9	0.007	0.001	0.709	0.69868
Interaction Y X C	1	0.329	0.329	319.647	0.00000
Interaction T X Y X C	9	0.029	0.003	3.109	0.00303
Error	78	0.080	0.001		
Total	**119**	**106.806**			
Organic carbon					
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Significance**
Replication	2	0.002			
Treatment T	9	1.194	0.133	297.223	0.00000
Year Y	1	0.140	0.140	313.775	0.00000
Interaction T X Y	9	0.005	0.001	1.311	0.24487
Condition C	1	0.232	0.232	520.369	0.00000
Interaction T X C	9	0.010	0.001	2.570	0.01208
Interaction Y X C	1	0.024	0.024	53.910	0.00000
Interaction T X Y X C	9	0.002	0.000	0.447	0.90498
Error	78	0.035	0.000		
Total	**119**	**1.645**			
Available nitrogen					
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Significance**
Replication	2	4.946			
Treatment T	9	92747.586	10305.287	10093.870	0.00000
Year Y	1	5239.376	5239.376	5131.888	0.00000
Interaction T X Y	9	356.542	39.616	38.803	0.00000
Condition C	1	5040.438	5040.438	4937.031	0.00000
Interaction T X C	9	281.752	31.306	30.663	0.00000
Interaction Y X C	1	2.858	2.858	2.799	0.09833
Interaction T X Y X C	9	8.721	0.969	0.949	0.48829
Error	78	79.634	1.021		
Total	**119**	**103761.851**			

Available phosphorus					
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Significance**
Replication	2	41.047			
Treatment T	9	8524.552	947.172	1146.754	0.00000
Year Y	1	463.961	463.961	561.724	0.00000
Interaction T X Y	9	46.226	5.136	6.219	0.00000
Condition C	1	334.051	334.051	404.440	0.00000
Interaction T X C	9	9.157	1.017	1.232	0.28815
Interaction Y X C	1	0.011	0.011	0.013	0.00000
Interaction T X Y X C	9	0.443	0.049	0.060	0.99995
Error	78	64.425	0.826		
Total	**119**	**9483.853**			

Available potassium					
Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Significance**
Replication	2	1.105			
Treatment T	9	76255.784	8472.865	13950.350	0.00000
Year Y	1	474.637	474.637	781.478	0.00000
Interaction T X Y	9	46.140	5.127	8.441	0.00000
Condition C	1	913.381	913.381	1503.857	0.00000
Interaction T X C	9	61.609	6.845	11.271	0.00000
Interaction Y X C	1	1.388	1.388	2.285	0.13469
Interaction T X Y X C	9	1.155	0.128	0.211	0.00000
Error	78	47.374	0.607		
Total	**119**	**77798.053**			

Appendix IV: Total cost of cultivation for lemongrass under control

Sr. No.	Items	Unit	Quantity	Rate	Total cost
1	**Material cost**				
	Planting material (slips)		82500	1	82500
2	**Labour cost**				0
	Ploughing	Hour	5	1000	5000
	Preparation of beds	Mandays	18	350	6300
	Planting	Mandays	10	350	3500
	Cost by annuity factor				14580.80808
	Weeding	Mandays	10	350	3500
	Irrigation	Mandays	5	350	1750
	Harvesting	Mandays	25	350	8750
	Transportation				1000
	Sub total				29580.80808
3	**Miscellaneous cost (2% of sub total)**				591.6161617
4	**Interest on working capital (4% of sub total)**				1183.232323
	Total variable cost				31355.65657
5	**Fixed cost**				
	Land rent				10000
	Depreciation				250
	Land revenue				31.25
	Interest on fixed capital (5% of sub total)				514.0625
	Total fixed cost				10795.3125
	Total cost				**42150.96907**

Appendix V: Total cost of cultivation for lemongrass under different treatments (Rs ha^{-1})

Sr. No.	Items	Unit	Quantity	Rate	Total cost
1	**Material cost**				
	Planting material (slips)		82500	1	82500
2	**Labour cost**				0
	Ploughing	Hour	5	1000	5000
	Preparation of beds	Mandays	18	350	6300
	Planting	Mandays	10	350	3500
	Cost by annuity factor				14580.80808
	Manure application	Mandays	10	350	3500
	Weeding	Mandays	15	350	5250
	Irrigation	Mandays	10	350	3500
	Harvesting	Mandays	30	350	10500
	Transportation				1000
	Sub total				38330.80808
3	**Miscellaneous cost (2% of sub total)**				766.6161617
4	**Interest on working capital (4% of sub total)**				1533.232323
	Total variable cost				40630.65657
5	**Fixed cost**				
	Land rent				10000
	Depreciation				250
	Land revenue				31.25
	Interest on fixed capital (5% of sub total)				514.0625
	Total fixed cost				10795.3125
	Total cost				**51425.96907**

Treatments	Cost of manures (Rs. ha^{-1})	Cost of cultivation of lemongrass (Rs. ha^{-1})	Total cost (Rs. ha^{-1})
T1(RDN)	1690.00	51425.97	53115.97
T2 (FYM)	48000.00	51425.97	99425.97
T3 (Vermicompost)	54854.40	51425.97	106280.37
T4 (Goat manure)	19998.00	51425.97	71423.97
T5 (Jeevamrut)	1000.00	51425.97	52425.97
T6 (FYM and RDN)	24845.00	51425.97	76270.97
T7 (Vermicompost and RDN)	28272.20	51425.97	79698.17
T8 (Goat manure and RDN)	10844.00	51425.97	62269.97
T9 (Jeevamrut and RDN)	1345.00	51425.97	52770.97

Appendix VI: Cost of cultivation of growing wild pomegranate in year 2021

Sr. No.	Items	Unit	Qty	Unit Rate	2021	Total cost
1	Site preparation	Mandays	10	100	1000	1000.00
2	Digging of pits	Mandays	13	100	1300	1300.00
3	Planting and filling of pits	Mandays	12	100	1200	1200.00
4	Cost of seedling	Seedlings	1250	30	37500	37500.00
5	Cost of FYM	kg	700	2.58	1806	1806.00
						42806.00
						3357.05
6	Basin preparation	Mandays	15	350	5250	5250.00
7	Pruning	Mandays	0	0	0	0.00
						8607.05
8	Miscellaneous (2% on total working capital)	Rs.				172.14
9	Interest on working capital (5%)	Rs.				430.35
10	Land rent	Rs.			3200	3200.00
11	Depreciation and maintenance	Rs.			66	66.00
Total cost of cult.		Rs.			51322	**12475.54**
Fixed cost was taken for the whole life of tree by annuity method						

Appendix VII: Cost of cultivation of growing wild pomegranate in year 2022

Sr. No.	Items	Unit	Qty.	Unit Rate	2022	Total cost
1	Site preparation	Mandays	10	100	1000	1000.00
2	Digging of pits	Mandays	13	100	1300	1300.00
3	Planting and filling of pits	Mandays	12	100	1200	1200.00
4	Cost of seedling	Seedlings	1250	30	37500	37500.00
5	Cost of FYM	kg	700	2.58	1806	1806.00
						42806.00
						3357.05
6	Basin preparation	Mandays	15	350	5250	5250.00
7	Pruning	Mandays	10	350	3500	3500.00
						12107.05
8	Miscellaneous (2% on total working capital)	Rs.				242.14
9	Interest on working capital (5%)	Rs.				605.35
10	Land rent	Rs.			3200	3200.00
11	Depreciation and maintenance	Rs.			66	66.00
Total cost of cult.		Rs.			54822	**16220.54**
Fixed cost was taken for the whole life of tree by annuity method						

Appendix VIII: Return from different components of wild pomegranate

Returns 2022					
Sr no.	**Components**	**Unit**	**Qty.**	**Unit Rate**	**Total**
1	Anardana/Aril yield	Rs/kg/ha	187.50	300.00	56250.00
2	Rind yield	Rs/kg/ha	1062.50	75.00	79687.50
Gross return (Rs/ha)					**135937.50**
Net return (Rs/ha)					**119716.96**

Department of Silviculture and Agroforestry
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Title of the Thesis	**:**	**“Effects of organic manures on growth, yield and oil quality parameters of lemon grass under wild pomegranate based agroforestry system”**
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Minor Discipline	**:**	Agroforestry
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ABSTRACT

The present investigation entitled **“Effects of organic manures on growth, yield and oil quality parameters of lemon grass under wild pomegranate based agroforestry system”** was conducted during 2021-2022 at the experimental farm of Department of Silviculture and Agroforestry, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan (HP). The study aimed to ascertain the effect of planting conditions and organic manures on growth, yield and quality parameters of lemongrass, soil physico-chemical properties and bio-economics of the system. The experiment was laid in Randomized Block Design comprising of two planting conditions (wild pomegranate-based agroforestry system and open condition) under which lemongrass was grown and applied with 10 treatments *viz*., T_1: Recommended dose of nitrogen, T_2: FYM (on nitrogen equivalent ratio basis), T_3: Vermicompost (on nitrogen equivalent ratio basis), T_4: Goat manure (on nitrogen equivalent ratio basis), T_5: Jeevamrut @ 500 l/ha (5 %), T_6: FYM and RDN on 50:50 equivalence basis, T_7: Vermicompost and RDN on 50:50 equivalence basis, T_8: Goat manure and RDN on 50:50 equivalence basis, T_9: Jeevamrut and RDN on 50:50 equivalence basis, T_{10}: Control. The results revealed that growth, yield and quality parameters of lemongrass were better under open condition compared to agroforestry system. Among different nutrient sources, treatment T_8 (50 % goat manure + 50 % RDN) resulted in higher plant height, number of tillers per plant, plant spread, fresh & dry herb yield, oil yield, Citral a and Citral b content, showing superiority of integrated nutrient management in increasing growth and quality parameters over sole application of organic manures or inorganic fertilizers. The physical and chemical properties of soil i.e., soil moisture (%), electrical conductivity, organic carbon, available N, P and K were higher in T_4 (goat manure) under wild pomegranate-based agroforestry system compared to sole cropping. Whereas, net return (Rs 173935.93 ha^{-1}) and benefit cost ratio (3.25) was recorded maximum in integrated nutrient treatment i.e., T_8 (50 % goat manure + 50 % RDN) under agroforestry system than in open condition. Based on the findings of this study, it can be concluded that integration of inorganic fertilizers with organic manures in agroforestry system can be used with optimum rates to improve crop productivity on sustainable basis.

Signature of Major Advisor **Signature of the student**

Countersigned

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(Mitali Mehta)