

**PERFORMANCE EVALUATION OF LETTUCE PRODUCTION INFLUENCED
BY DIFFERENT FERTILIZER APPLICATIONS IN MORINGA BASED
AGROFORESTRY SYSTEM**



A THESIS

BY

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STUDENT ID. 1601084

SESSION: 2023

SEMESTER: JANUARY-JUNE, 2024

MASTER OF SCIENCE (M.S.)

IN

AGROFORESTRY AND ENVIRONMENT

**DEPARTMENT OF AGROFORESTRY AND ENVIRONMENT
HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY,
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HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY,

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JUNE, 2024

**DEDICATED
TO MY
BELOVED FAMILY**

CERTIFICATE OF DECLARATION

I affirm that the research work presented in this thesis entitled "**PERFORMANCE EVALUATION OF LETTUCE PRODUCTION INFLUENCED BY DIFFERENT FERTILIZER APPLICATIONS IN MORINGA BASED AGROFORESTRY SYSTEM**" is solely my own work and has not been submitted for any previous academic degree. Any direct quotations used in this thesis have been appropriately cited with quotation marks, and all sources of information have been duly acknowledged through references to the respective authors.

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The Authoress

PERFORMANCE EVALUATION OF LETTUCE PRODUCTION INFLUENCED BY DIFFERENT FERTILIZER APPLICATIONS IN MORINGA BASED AGROFORESTRY SYSTEM

ABSTRACT

The demand and production of lettuce in Bangladesh are facing challenges due to suitable land, changing weather and climate. A potential alternative is cultivating lettuce in vertical agricultural production systems i.e. under agroforestry systems, but information about lettuce production systems and fertilizer application in different agroforestry systems is scarce. Therefore, this investigation was conducted to identify suitable lettuce production systems and eco-friendly, cost-effective fertilizers applications to maximize lettuce productivity in different systems. The research was conducted at the Department of Agroforestry and Environment of Hajee Mohammad Danesh Science and Technology University, Dinajpur, using two experimental field, one is open i.e. “lettuce sole” and other experimental field with a moringa orchard (variety: Baromashi; age of tree: 6 years; tree spacing: 4m × 4m; Planting orientation: north-south). The experiment involved two lettuce production systems (“lettuce sole- S_1 ” and “lettuce + moringa- S_2 ”) and four fertilizer application packages- F_1 (chemical fertilizers @ FRG.2014), F_2 (cow dung @ 10 t ha⁻¹), F_3 (poultry manure @ 5 t ha⁻¹) and F_4 (No fertilizer). The experiment was carried out using a Randomized Complete Block Design (RCBD) with three replications. The total number of experimental plots of lettuce were 24. All the lettuce seedling in two production systems were sown using spacing of 40m×25cm per plot. The result of the experiment revealed that the different production systems had significant effect on all the growth and yield parameters like Plant height, number of leaves, leaf length, leaf breadth, weight of leaves. Yield of lettuce was also varied significantly, and the best yield (20.39 t ha⁻¹) was recorded from production system S_2 (Lettuce + Moringa) whereas, the lowest yield (10.05 t ha⁻¹) was observed from production system S_1 (Lettuce sole). In case of fertilizer applications, chemical fertilizer gave the best yield (22.51 t ha⁻¹) while no fertilizer gave the lowest yield (10.52 t ha⁻¹). The maximum dry matter content (14.69%) from S_1F_1 (Lettuce sole + chemical fertilizer) and ash content (3.37%) was recorded from S_1F_2 (Lettuce sole + cow dung) and the minimum dry matter content (9.05%) and ash content (0.91%) was recorded from S_2F_1 (Lettuce with moringa + chemical fertilizer) treatment. From the economic analysis, it was observed that the higher BCR 5.07 was recorded from production system S_2F_4 (Lettuce + Moringa) with no fertilizer application under moringa based agroforestry system. So, it was interesting about the research between two production systems that lettuce production in open field with no fertilizer application gave lower yield of lettuce than other fertilizer applications, when the economic return of S_2 (Lettuce with Moringa) production is combined with economic return of moringa trees gave higher BCR which may be beneficial to moringa garden owner. The lower BCR 3.48 was from S_1F_2 (lettuce sole) with cow dung application. Finally, it may be concluded that the production system “Lettuce with Moringa” can be cultivated successfully in this region and further research should be done for final packages of fertilizer applications.

Key words: Production system, Lettuce, Agroforestry, Quality, Effect, Yield and Fertilizer application.

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ACRONYMS AND ABBREVIATIONS

%	Percent
@	At the rate
°C	Degree Celsius
µg	Microgram
AEZ	Agro-Ecological Zone
AGF	Agroforestry
ANOVA	Analysis of Variance
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of statistics
BCR	Benefit Cost Ratio
cm	Centimeter
DAS	Days after sowing
FAO	Food and Agriculture organization
<i>Et al.</i>	And others
etc.	Etcetera
g	Gram
ha	Hectare
Kg	Kilogram
Klux	Kilo-lux
MoP	Muriate of Potash
No.	Number
PAR	Photosynthetically Active Radiation
pH	Puissance of Hydrogen
RCBD	Randomized Complete Block Design
TSP	Triple Super Phosphate
t ha ⁻¹	Ton per Hectare
tk	Taka
wt.	Weight

CHAPTER I

INTRODUCTION

Bangladesh is one of the most densely populated countries in the world struggling hard to feed her more than 170 million people. The current population growth rate is 1.22% and the density of human population is 1156.84 per sq. km. (UNFPA, 2022). As a result, the country faced some shortage of green vegetables enriched with vitamins and minerals. Therefore, to meet the domestic requirement of green vegetables, there is no other way for expansion of vegetable cultivation. We can increase our vegetable-Plant coverage through practicing agroforestry. About 40.60% of the gross domestic product of Bangladesh is contributed from agriculture employment sector. Of the total agricultural product about 4.98% comes from crops and horticulture, 4.47% from livestock, 6.57% from fishes and 7.97% from forests (BBS, 2021).

Lettuce (*Lactuca sativa* L.) is an annual Plant that belongs to one of the important vegetables in the salad Plant family *Compositae*. It is the world's most sought-after salad Plants. It is native to Europe, Asia and North Africa, and has been grown for 5000 years. The word “lettuce” is often used to refer to the succulent, edible L leaves. *Sativa* usually consumed raw in salads but can also be cooked (Katz and Weaver, 2003).

Lettuce is one of the most widely consumed vegetables in the world as it is a good source of fiber, but it has low calories, fat and sodium. Besides, it is a good source of iron, folic acid, and vitamin C, and very good for health from various bioactive compounds (Kim *et al.*, 2016). Lettuce is an annual herbaceous Plant that grows upright from (12.5 to 25) cm in leaves, with Plant height up to 50 cm in length (Ali *et al.*, 2016). Lettuce ranks 26th out of 39 vegetables with a high nutritional value and is the fourth feed. It's primarily a cold-loving Plant that grows well at 18 to 25°C daytime temperature and 10 to 15°C night temperature (Prota, 2010).

Organic fertilizers not only have the required nutrients but also have positive effects on overall soil productivity and can be used effectively in traditional farming as an essential fertilization method (Bharambe, 2015). State of the soils and their state of health is important for agricultural production.

Degraded soils and low soil productivity are the major constraints to food security and income levels of smallholder farmers in developing countries like Bangladesh who are so

dependent on the land and deeply attached to it for their survival (Natsheh *et al.*, 2015; WOCAT, 2007; Spore, 2009).

Owing to the high mineralization rates, the Mediterranean climate is mostly characterized by clay soils and a substantial annual loss of organic matter. Large uses of mineral fertilizers have significantly led to environmental degradation (atmosphere, soil, and water) in recent decades. One of the potential solutions for minimizing the use of chemical fertilizers could be the implementation of organic modifications from agricultural waste recycling. Compost application is a good method, as field recycling and agro-industrial residues provide many agricultural benefits, e.g. soil preservation/restore organic carbon (C) and Plant disease control (Hoitink *et al.*, 2001; Flavel and Murphy, 2006; Raviv *et al.*, 2008) also pointed out that its application constituted a relatively cheap nutrient source. Because of the environmental effects of mineral fertilization, organic fertilization may be a better choice, with the Plant, soil and environment benefits (Leogrande *et al.*, 2013).

Since fertilization and irrigation activities tend to be some of the causes of nitrate contamination, the use of the new organic residues must be investigated (Guerrero *et al.*, 2005); on the other hand, effective management of the application of inorganic fertilizers has been shown to minimize the issue of nitrogen leaching in soil and groundwater (Guerrero *et al.*, 2002).

Compost application to soil is environmentally sustainable, particularly in soils with lower fertility, characteristic of southern Portugal, increasing soil fertility and improving Plant production (Brito *et al.*, 2007). Compost was already applied as organic fertilizer to lettuce (*Lactuca sativa* L.) and aspects of quantitative and qualitative yield were studied (Alvares *et al.*, 2002). The chemical fertilizers used in conventional agriculture contain just a few minerals, which quickly dissolve in damp soil and give large doses of minerals to the Plants. Organic fertilizers can therefore be used to re-duce the number of toxic compounds (such as nitrates) produced in vegetables such as lettuce by conventional fertilizers, thereby improving the quality of the leafy vegetables produced as well as human health (Masarirambi *et al.*, 2010).

Currently, people are willing to get vegetables without inorganic fertilizer because people suffer from some severe diseases due to the inorganic fertilizer effect (Asaduzzaman *et al.*, 2010). With growing consumer concerns about the environment

and the chemicals used in food production, and the availability of certified organic products, the outlook for the continued growth of organic production is bright (Dimitri and Greene, 2002). Farm income will also increase as farmers use less money to grow Plants with fertilizers and pesticides (Masarirambi *et al.*, 2010).

Moringa oleifera (drumstick) is one of the most cultivated vegetables in many tropical and subtropical nations, including Bangladesh. It is one of the most versatile and priceless multifunctional trees in the world and has a great tolerance to drought in addition to its medicinal and nutritional benefits. As a result, it has earned the names "mother's best friend tree" and "miracle tree" throughout the world (Devkota and Bhusal, 2020).

Different types of food ingredients such as- protein, fiber, calcium, phosphorus, potassium, sulfur, iron, ascorbic acid, carotene, choline, thiamine, riboflavin, and nicotinic acid in its leaves and roots are sufficient (Anwar *et al.*, 2005). Moringa is a significant homestead species that is haphazardly grown alongside highways all over Bangladesh. But there is a good scope to establish moringa tree-based orchard in high land close to the homestead. All parts of moringa (leaves, fruits, immature pods and flowers) are edible and popular as a traditional food for human consumption. Apart from the use of young pods as delicious vegetables, leaves are rich in easily digestible protein, minerals, and vitamins (El Sohimy *et al.*, 2015; Witt, 2016).

While regular vegetative propagation utilizing branches that are a year old is substantially faster, seed propagation takes a lot longer. Increased leaf biomass output can be attained by quick proliferation and the use of appropriate cultivation methods, allowing us to use it as a cheap, nutrient-rich vegetable in our daily diet. Therefore, moringa can significantly help Bangladesh and other poor nations like it overcome malnutrition and poverty. Moringa Plant parts easily break down into soil, which is good for many Plants that don't have enough storage space. Normally, all of the branches of the moringa trees were clipped or cut down after harvest. As a result, a significant amount of light can pass through the canopy of moringa trees, which is crucial for Plants with little storage. The agroforestry with moringa plays a vital role in soil and water conservation (Devkota and Bhusal, 2020).

It's interesting to note that vegetables growing in the understory of moringa trees can benefit from increased nutrient dynamics and light accessibility due to leaf litter

(Agbogidi and Ilondu, 2012). So, cultivation of Lettuce under moringa based agroforestry system may be beneficial to improve soil properties and to increase the yield of lettuce.

Balanced fertilizer application is essential for the vegetative growth and, thus, for producing Plants with top quality and high yields especially on soils that are cultivated continuously (Chintala, McDonald, and Bryan, 2012a, 2012b).

Application of all needed nutrients through chemical fertilizers is also known to have deleterious effect on soil fertility leading to unsustainable yields. So, despite chemical fertilizer, organic fertilizer i.e., manuring like cow dung, poultry manure etc. are also good for lettuce cultivation. The ability of poultry manure to increase the performance of lettuce could also be attributable to the fact that organic manures improve both physical and chemical soil properties (Yahaya, 2008).

Optimized use of fertilizers through judicious combination of organic resources and mineral fertilizers at levels sufficient to replenish soil nutrients removed by the Plants is crucial so as to enhance productivity and keeping wellbeing of the environment (Ouedrago *et al.*, 2002).

However, by cultivating extra uncultivated area, such as the floor of a garden or a woodlot, we can produce more lettuce. Lettuce can be cultivated on the ground of a young fruit garden or woodlot, and this should result in higher yields. However, we need some technologies for this agro-farming method, such as proper fertilizer and manure applications under each individual tree-based garden. Additionally, using organic manuring may be a wise choice for a safer food production process and a better environment. Regrettably, the current state of knowledge in Bangladesh regarding the impact of various fertilizer and manure applications on screening lettuce production system suitable for Moringa-based agroforestry systems remains limited. As a result, a comprehensive study was undertaken to address this knowledge gap. This study involved the meticulous examination of different production systems and fertilizer treatments in conjunction with two distinct lettuce production systems, all cultivated beneath the canopy of Moringa trees. The primary objective was to identify the most effective and compatible combinations that would optimize lettuce production within different production systems and fertilizer application.

Objectives of the research work:

1. To evaluate the impact of different production systems on the growth, yield, and quality attributes of "BARI Lettuce-1" in open field and moringa orchard settings.
2. To assess the impact of different applications of fertilizers, cow dung and poultry manure on the growth, yield and quality of lettuce under different production systems.
3. To estimate the economic output of "BARI Lettuce-1" using different chemical fertilizers, cow dung, poultry manure and no fertilizer under different production systems.

CHAPTER II

REVIEW OF LITERATURE

Lettuce is the most significant salad type vegetable in Bangladesh as well as the rest of the world. The research was executed to evaluate performance of lettuce production influenced by different fertilizer applications under moringa based agroforestry system. There have been many experiments on the lettuce Plant around the world, but still there is a lack of knowledge regarding the application of various fertilizer and manure packages in lettuce Plant and their effects on growth, yield, and quality parameters under moringa based or any other tree-based agroforestry systems. Although there is a vast quantity of literature to understand different aspects of agroforestry systems, it is insufficient for quantifying the biological interactions among the various parts of these systems. This chapter represents a brief review of the pre studies and statements of researchers relevant to this experiment which are collected from different sources i.e. literature, journals, thesis, reports, etc. Brief summaries of the pertinent literature that is currently accessible have been evaluated in this chapter under the following heads:

2.1 Concepts of Agroforestry

2.2 Amenities of Agroforestry Systems

2.3 Moringa Based Agroforestry

2.4 Nutritional Values, Products and Services from Moringa

2.5 Consumption and Benefits of Lettuce

2.6 Effects of Fertilizers on Lettuce Production

2.1 Concepts of Agroforestry

Agroforestry, the practice of growing trees and crops in interacting combinations, is recognized across the world as an integrated approach to sustainable land-use. Agroforestry systems, being multifunctional, facilitate not only the production of food and wood products but also provide a variety of ecosystem services such as climate-change mitigation, biodiversity conservation, and soil quality improvement (Nair *et al.*, 2021).

Agroforestry includes various multipurpose tree species which are grown along with various annual crops like, rice, wheat, and other seasonal vegetables in farmer's land.

The system provides food, fuel, timber, construction materials, raw materials etc. Soil conservation and improvement have been one of the most important functions of this system (Miah *et al.*, 2018).

Agroforestry can be defined as a dynamic, eco-friendly, natural resource management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels (FAO, 2015).

Agroforestry is a land use system that integrates trees and crops on the same unit of land for multiple benefits. It is based on four main concepts: productivity, sustainability, diversity, and compatibility. Productivity refers to the ability of agroforestry systems to produce more biomass and yield than monocultures, due to positive interactions among the components. Sustainability means that agroforestry systems can maintain or enhance the natural resource base, such as soil fertility, water quality, and biodiversity, over time. Diversity implies that agroforestry systems can support a variety of Plant and animal species, as well as provide different products and services for the farmers and consumers. Compatibility means that agroforestry systems can fit well with the local ecological, social, and economic conditions, and adapt to changing needs and circumstances (Leakey, 2014).

Agroforestry is a new name for a set of old practices. Agroforestry as a land use system that integrates trees, crops and animals in a way that is scientifically sound, ecologically desirable, practically feasible and socially acceptable to the farmers (Nair, 2013).

Agroforestry is considered as a production technique where agricultural crops are grown in combination with tree species on the same piece of land to maximize the utilization of natural resources like land, sunlight, water owing to get more profit. This farming technique has been expanded in a large scale to meet the food demand of Bangladesh (Ahmed *et al.*, 2013).

2.2 Amenities of Agroforestry Systems

Akter *et al.* (2022) investigated the composition of and preferences by farmers related to trees and crops Planted in agroforestry systems, and their role on the livelihood of tribal farmers in a tropical moist deciduous forest in Tangail, Bangladesh. Interviews revealed that agroforestry systems have provided numerous benefits and greatly enhanced farmers' livelihoods through better access to food, timber, fodder, and fuel-wood and

greater access to livelihood capitals (except social capital). Though agroforestry practices increase species diversity, provide economic returns, and help farmers maintain their livelihoods, tribal farmers face several constraints including bureaucracy and a lack of alternative market facilities.

Meragiaw *et al.*, (2022) investigated the land use and land cover (LULC) dynamics and the status of traditional agroforestry practices provided important data for policymakers. The results of LULC changed from 1985 to 2019 showed that the agroforestry cover increased from 31.1% to 34.9% and settlement including road construction increased from 12.5% to 31.6% of the total area with an annual rate change of 0.3% and 2.7%, respectively.

Lojka *et al.*, (2021) reported that agroforestry (AF) is an example of "Sustainable Intensification", or how to get more outputs and greater diversity with fewer inputs. Hence, it addressed the negative environmental impacts of intensive agriculture, and its vulnerability to changing climate. Well-designed AF systems, which were adapted to local conditions, had a great capacity to provide economic benefits (in terms of higher productivity per se or reduced risks of production loss to biotic and/or abiotic stresses), while increasing the heterogeneity at the landscape level, which was beneficial for biodiversity conservation and ecosystem functioning.

Ahmed *et al.*, (2020) analyzed a study to enumerate quantification of the land potential for scaling agroforestry in south Asia. The analysis revealed that 69% of the total geographical area retains 55% and greater suitability for agroforestry. The analysis revealed that nearly 73.4% of the landscape is absent (0%) of tree cover, 7.1%, shows 1-10% and 19.5% area having more than 10% tree cover.

Pavlids and Tsihrintziz (2018) reported that tree roots in agroforestry systems are able to reduce nitrogen and phosphorus residues in soils from 20% up to 100%, have the potential to reduce pesticides leaching and runoff in considerable amounts (up to 90% for runoff), and simultaneously they provide additional benefits to the ecosystems including erosion control, improvement of soil quality and positive effects on biodiversity. Agricultural pollution consists a serious concern for environmental protection managers. Among the pollutants, nitrates, phosphoric compounds and organic pesticides from agricultural activities are the most common and hazardous to the environment and human health. Several mitigation techniques have been proposed to control these

pollutants from entering aquatic systems. Agroforestry, which is the common cultivation of crops and trees, is one such mitigation technique.

Rahman, (2012) stated that agroforestry systems are preferable to mono-cropping as they are able to generate income from agricultural crops, tree sales and carbon trading programs, such as REDD+ schemes. Agroforestry can be the most effective way to reduce deforestation in Bangladesh which could bring 'win-win' solutions to meet both environment and development objectives.

Agroforestry can be recognized as potential solution to meet the needs of the society as well as sustainable development models due to its benefits not only to the economy and society but also to the ecosystem (Bargali *et al.*, 2009; Thanh, 2005). Farmers can benefit from agroforestry technologies that give solutions to issues with soil productivity, product diversification, and economic problems (Franzel and Scherr, 2002).

Alavalapati *et al.* (2004) stated that Agroforestry systems (AFS) provide a mix of market goods and nonmarket goods and services. We postulate that if nonmarket goods and services can be internalized to the benefit of landowners, the adoption of AFS will increase. It has been found that the profitability of silvopasture would increase, relative to conventional ranching, if environmental services are included. Estimates of public willingness to pay for environmental services associated with silvopasture and estimates of ranchers' willingness to accept for the adoption of silvopasture will provide a scientific basis for policy development.

Brandle (2004) listed the following economic benefits of Agroforestry such as:

1. When various species are included in the design, they can contribute directly to the production of nuts, fruits, timber and other wood products. This helps to diversify and increase farming income while also providing a stock of capital in valuable timber.
2. When used in livestock production systems, they improve animal health, improve feed efficiency and contribute to the economic returns of producers.
3. The practices can also help to reduce energy consumption by the farm and improved working conditions within the farm area, which helps to save cost and increases productivity.

4. Agroforestry technology can reduce costs of production, increase productivity and provide multiple outputs.

Haque (1993) mentioned that agroforestry as a means to meet the dimensional needs of the rural people in terms of food, fuel, timber, construction materials, thereby helping them to lead a self-sustained life. It is estimated that about 80-82% of forest products produced annually in the country come from this agroforestry farming system (GOB, 1992).

2.3 Moringa Based Agroforestry

Pantera (2021) stated that *Moringa oleifera* (Lam) had represented a promising choice in arid zones where water was a limiting growth factor. Based on the results from greenhouse and field research conducted in Tunisia, it appeared that *Moringa oleifera* could withstand severe water stress while maintaining sufficient root and foliar growth, rendering this species a valuable candidate to rehabilitate and enhance soil quality in arid zones for agroforestry system.

Vijaykumar *et al.*, (2021) carried out a field experiment at Forest Nursery and research Centre (College of Forestry) of Sam Higginbottom University of Agriculture, Technology and Sciences Prayagraj during kharif season with sixteen treatments replicated thrice in a randomized block design to estimate the performance of rice growth and yield under (*Moringa oleifera* L.) based Agroforestry system with utilization of various types of manures. Among the organic manure, green manure, green leaf manure with control treatments, result showed that significantly and the maximum performance of Grain yield observed in T₆ (41.31 q ha⁻¹) (50% Goat manure + 50% *Crotalaria juncea*) followed by T₁₀ (41.21 q ha⁻¹) (50% Goat manure + 50% *Pongamia glabra*) respectively and minimum Grain yield recorded in T₀ (37.61 q ha⁻¹) (control).

Devkota and Bhusal (2020) studied an experiment to evaluate the multiple effects of moringa tree species for agroforestry practice in Nepal. The result showed that moringa alley cropping decreased soil acidity and multiple uses of the tree facilitated its production.

Gandji *et al.*, (2020) conducted a field experiment to evaluate morphological diversity of the agroforestry species *Moringa oleifera* as related to ecological conditions and farmers'

management practices in Benin. The result showed that significant variation in pod diameter of moringa between bio-geographical zones.

Sumona *et al.* (2018) conducted research to find out the response of red amaranth in association with drumstick (*M. oleifera* L.) sapling. The experiment was conducted at agroforestry experimental field, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207 during February to March 2018. Four treatments namely, T₁= 12.0 cm distance from the tree base, T₂= 24.0 cm distance from the tree base, T₃= 36.0 cm distance from the tree base and T₄= Open field referred to as control, were used in Randomized Complete Block Design (RCBD) with four replications. At harvest, Plant height in treatment T₃ was 25.0 cm which was statistically similar with the Plant height observed in control condition (T₄). However, at harvest 22 % less stem girth was found in the Plants under T₃ treatment compared to the Plants of control treatment. The significantly highest leaf length (5.77 cm) and breadth (3.75 cm) were observed in the Plants under control treatment (T₄) which were closely followed by the Plants of T₁ treatment with the values of 4.52 cm and 3.32 cm, respectively. Among the agroforestry treatments, the highest leaf number, shoot length, and root length were found in T₃ treatment which were only 15.0 % (leaf number), 13.0 % (shoot length) and 7.0 % (root length) less than that of control condition. Apart from control treatment, the highest fresh weight, dry weight and yield were obtained in the Plants under T₃ treatment. The highest moisture content (94.2%) and dry matter content (6.3%) of red amaranth were found in the Plants of T₁ and T₃ treatment, respectively. Thus, it revealed that in association with Moringa sapling the optimum performance of red amaranth was found in the Plants under T₃ treatment. Therefore, farmers may cultivate red amaranth in association with Moringa sapling up to six months by maintaining 18.0 cm distance from tree base.

Tafese *et al.*, (2020) conducted a study to estimate technical efficiency of moringa production for agroforestry system in southern Ethiopia. The study was surveyed on sampled 117 Moringa producer farmers from southern Ethiopia. The Stochastic Frontier Model was used to estimate the level and factors determining the technical efficiency of Moringa production. An estimated level of efficiency showed that the possibility of farmers to increase Moringa output by 47.81% with existing inputs and technology.

Shahapurmath *et al.*, (2020) conducted a field experiment to assess the growth and yield performance of fodder tree species with intercrops in karnataka, India. The highest current annual increment (CAI) in diameter at breast height was recorded in *Moringa*

oleifera (2.31 and 2.12 cm). The highest CAI in volume of wood was reported in *Moringa oleifera* (5.042 and 5.62 m³ ha⁻¹).

Yohannes *et al.* (2016) said that Agroforestry is praised for its benefit in balancing economic and environmental goals although its economic advantages over mono-cropping were not well documented for most agro-ecology and practices. He also studied an experiment and the result shows that moringa based agroforestry is practiced by most of the respondents. The comparison between moringa based agroforestry and mono-cropping revealed that Moringa tree-based agroforestry practice is more profitable than mono-cropping system. It is not only the profitability but also the moringa based agroforestry over rides the mono-cropping by being less sensitive for changes in price and other variables. The result shows that Moringa tree-based agroforestry system is superior for its social, economic, and environmental benefits than mono-cropping system. Above all, it is the land use system recommendable in the area, where the problem of inhospitable, harsh and vulnerable environments, challenging landscape, fragile soil susceptible to erosion and highly variable rainfall is very pressing. Therefore, the government and other responsible bodies should give due attention to help smallholder farmers in the area in order to use Moringa tree-based agroforestry land use in addition to mono-cropping.

Abdullahi *et al.* (2014) stated that in the Guinea Savannah region of Nigeria, farmers (including women) are growing *Moringa oleifera* as the woody perennial crop on their farmlands is increasing. The tree, though not a nitrogen-fixing Plant, is among the known promising exotic multipurpose tree species recommended for fuel wood, fodder, food, medicinal value, and soil fertility improvement.

Larwanou *et al.* (2014) reported that seed yield of soybean; irrespective of treatments was 20% greater than the previous cropping season. During the second year of cropping, the Moringa component was well established, and the non-harvestable portion were pruned and spread as green manure. The exercise thus may have improved the fertility status of the soil to the benefit of the companion crop as discussed in and that Moringa leaves extract improves growth and productivity.

Anjorin *et al.* (2010) said that leaves of *M. oleifera* are rich in zeatin, acytokin in addition to other growth enhancing compounds like ascorbates, phenolic and minerals like Ca, K and Fe that makes it an excellent crop growth enhancer.

2.4 Nutritional Values, Products and Services from Moringa

Nutritional Values

Khalid *et al.* (2023) conducted research on moringa leaf extract to find its nutritional value to human health. He stated that *Moringa oleifera*, a food Plant, has potential as antioxidant, antimicrobial agent, anti-inflammatory, and anti-diabetic. The investigation was planned to extract bioactive compounds from *Moringa oleifera* leaf powder (MoLP). Moringa leaves were collected, dried, and ground, and the aqueous and ethanolic extracts of MoLP were prepared by maceration and then characterized for phytochemical profiling by HPLC and Fourier transform infrared (FTIR) spectroscopy. HPLC of *Moringa oleifera* leaf extract (MoLP) revealed that 70% extract contain more concentrations of quercetin (45.01 ppm), folic acid (3.26 ppm), chlorogenic acid (8.45 ppm), p-coumaric acid (1.38 ppm), ferulic acid (5.82 ppm), and sinapic acid (2.64 ppm). FTIR spectroscopy was performed to investigate the functional group profile of *Moringa oleifera* leaf extract. The FTIR analysis identified the presence of major functional groups including alcohols, alkanes, alkenes, nitro compounds, ether, ester, carboxylic acid, aromatic, aliphatic bromo compounds, aryl disulfide, isocyanates, and phenols. The research showed that the phytochemicals in *Moringa oleifera* act as antioxidant to stabilize free radicals and recommended to be used in human diet as food supplements.

Penalvar *et al.* (2022) studied the Nutritional and Antioxidant Properties of *Moringa oleifera* Leaves in Functional Foods. Due to its richness in minerals and macronutrients, the antioxidant capacity and the mineral bioaccessibility were assessed. In addition, the chemical composition, amino acid, fatty acid, and mineral content were also evaluated. The performed analysis reported a high content of proteins and low content of lipids in the chemical composition. Regarding the mineral content, Ca and Fe presented high bioaccessibility; K, S, Ca, and Fe being the most concentrated elements. The obtained values using FRAP, ABTS, and ORAC methods showed high antioxidant capacity, directly related to the increased content of phenolic compounds. In view of the results, *Moringa oleifera* can be incorporated into the diet as a functional ingredient or as a fortifier of any kind of food. The important source of minerals, phenolic, proteins, unsaturated fats, and folates make it an excellent extract with beneficial properties.

Fahey, (2019) revealed that Moringa leaves contain more vitamin A than carrots, more Vitamin C than an orange, more potassium than bananas, and on top of that, the protein quality of Moringa leaves competes with that of milk and eggs.

Ravani *et al.* (2017) referred *Moringa oleifera* as a miracle tree due to its rich source of certain macro and micro nutrients of great importance in human nutrition. Almost every part of the moringa tree, viz. fruit, flower, seed, bark, root and gum is a rich repository of proteins, vitamins and minerals including potassium, calcium, phosphorous, iron, folic acid as well as p-carotene. The review covered health benefits of moringa as well as technology of post-harvest handling and processing of moringa for utilization in value added products. He reviewed that there is considerable variation among nutritional values of moringa, which depends on factors like genetic background, environment and cultivation methods. The Plant was proven with tremendous medicinal properties. The author described moringa as one of the most amazing trees God has created.

According to Chukwuebuka (2015) comparison of Moringa fresh and dry leaves with common foods per 100 grams were:

Nutrients	Common foods	Moringa Leaves	
		Fresh Leaves	Dried Leaves
Vitamin A	1.8 mg Carrots	6.8 mg	18.9 mg
Calcium	120 mg Milk	440 mg	2003 mg
Potassium	88 mg Banana	259 mg	1324 mg
Protein	3.1 g Yogurt	6.7 mg	27.1 mg
Vitamin C	30 mg Orange	220 mg	17.3 mg

Zaku *et al.*, (2015) stated that Moringa is famous as an excellent source of nutrition and a natural energy booster. Each part of the Moringa tree (fruits, seeds, leaves, flowers, bark and roots) is associated with the presence of at least one, or in the greatest number of benefits.

Saini (2014) revealed that iron from Moringa can overcome iron deficiency. The analysis of dietary iron supplements in the liver was influenced by *M. oleifera* leaves. It has been promoted by the WHO as an alternative food source to treat malnutrition (Sreelatha *et al.*, 2009).

2.5 Consumption and Benefits of Lettuce

Lettuce (*Lactuca sativa* L.) belongs to the largest dicotyledonous family in Plant kingdom, the compositae, it is the most popular salad Plants and occupies the lion share among salad crops in the world. It is an annual leafy bud with a milky juice. Lettuce is popular for its delicate, crisp texture and slightly bitter tang. It contains protein carbohydrates and vitamin C per hundred g. of edible portion of lettuce contain moisture 93.4g, protein 2.1g, fat 0.3g, mineral 1.2g, fiber 0.5g, carbohydrate 2.5g, calcium 320mg, phosphorus 80mg, iron 2.6mg, vitamin A 1650LU, thiamine 0.09mg, riboflavin 0.13mg and vitamin C 10mg (Gopalan and Balaraman, 1966). Moreover, it is anodyne, sedative, diuretic and expectorant (Kallo, 1986). Lettuce is a short duration crop but its market price is high. Being labor intensive, it can create great opportunities for employment. In a mixed production system with multiple Plant components there may have competitive, facilitative and complementary effect of each component on another. For obtaining the full benefits of agroforestry it is necessary to maximize the positive effects and to minimize the negative effects of trees on associated crops. For maximizing this beneficial effects and minimizing negative effects it is essential to observe the tree-vegetables/crops interactions from agroforestry systems.

2.6 Effects of Fertilizers on Lettuce Production

Hossain and Ryu (2017) conducted a greenhouse experiment to identify the suitable dose of organic fertilizer for lettuce production. Different doses of organic fertilizer (6.5, 13 and 26 t ha⁻¹) and the recommended dose of chemical fertilizer (RDCF) as standard were selected for this experiment. Application of 13 t ha⁻¹ organic fertilizer significantly increased leaf size (length and breadth) of lettuce. This treatment also increased 14, 25, 21, 32, 24, 27, 36 and 168% fresh weight, dry weight, N, P, K, Ca, Mg and Na uptake over RDCF, respectively. Organic matter content was increased of 17.79, 43.82 and 89.89% in 6.5, 13 and 26 t ha⁻¹ organic fertilizer treated plots respectively over recommended dose of chemical fertilizers. Data also indicated that organic fertilizer @ 26 t ha⁻¹ resulted in significant increase in pH, total nitrogen (24%), organic matter (90%) and Zn (29%) compared to RDCF and decreased electrical conductivity, mineral nitrogen (NH₄ + -N and NO₃ - -N) and cadmium and lead (Cd and Pb) in soil. Positive and significant correlation was observed on yield and yield attributes of lettuce and soil nitrogen, organic matter with pH, total nitrogen with mineral nitrogen and negative correlation was found with applied organic fertilizer with cadmium and lead. Based on

these results, organic fertilizer @ 13 t ha⁻¹ without chemical fertilizer could be recommended to increase lettuce yield as well as mitigate heavy metals in soil.

Basel Natsheh, Nawaf Abu-Khalaf (2020) conducted an experiment during the period from March to the end of April 2019 to observe the effect of different fertilizer regimes on the growth, quality and yield of lettuce under field conditions. The experiment was consisting of four treatments as well as a control without fertilizer T₁, compost T₂, compost tea T₃ and chemical fertilizer T₄, in each treatment 50 replicates were Planted. The measurements included wet and dry weight for shoot and root, Plant length, and chlorophyll percentage. The study revealed that lettuce's best growth values were obtained with the use of eco-friendly organic fertilizer accompanied by more than control one and chemical fertilizer. The average maximum length of Plants after 60 days was recorded in T₂ (42.3 cm) > T₃ (37.3 cm), T₄ (35.9 cm) and > T₁ (23.8 cm). The results indicated that compost treated Plant (T₂ and tea compost T₃) had highest chlorophyll content, i.e., 42.3 and 40.6%, respectively, as compared to chemical fertilizers T₄ (37.3%) and the lowest chlorophyll content was in control T₁ (30.9%). The values for wet shoot and root after 60 days were: 1575.2, 81.5 gm T₂ > 1367.6, 64.9 gm T₃ > 1251.1, 53.4 gm T₄ and 612.1, 43.7 gm T₁, respectively. The values for dry shoot and root after 60 days were: 131.5, 8.2 gm, T₂ > 112.7, 6.4 gm, T₃ > 101.9, 5.3 gm T₄ and > 51, 4.1 gm T₁, respectively.

Liu *et al.* (2014) conducted an experiment where they noticed that nitrogen is an essential element for Plant growth and development; however, due to environmental pollution, high nitrate concentrations accumulate in the edible parts of these leafy vegetables, particularly if excessive nitrogen fertilizer has been applied. Consuming these crops can harm human health; thus, developing a suitable strategy for the agricultural application of nitrogen fertilizer is important. Organic, inorganic, and liquid fertilizers were utilized in this study to investigate their effect on nitrate concentrations and lettuce growth. The results of this pot experiment show that the total nitrogen concentration in soil and the nitrate concentration in lettuce increased as the amount of nitrogen fertilizer increased. If the recommended amount of inorganic fertilizer (200 kg·N·ha⁻¹) is used as a standard of comparison, lettuce augmented with organic fertilizers (200 kg·N·ha⁻¹) have significantly longer and wider leaves, higher shoot, and lower concentrations of nitrate.

Another study was conducted by Islam *et al.* (2014) to observe the effects of different organic fertilizers on the growth and yield of lettuce in the field conditions during the period from October 2011 to January 2012. The experiment was performed by randomized block design consisted of four factors as well as control (without fertilizer), poultry manure (chicken litter), cattle manure (cow dung) and commercial fertilizer. Under these four factors, eight treatments namely T₀ (control); T₁, T₂ and T₃ (10, 20, 30 tons/ha of poultry manure, respectively); T₄, T₅ and T₆ (15, 25, 35 tons/ha of cattle manure, respectively); and T₇ (10 tons/ha commercial fertilizer), with three replications were applied. The studies revealed that the highest production of lettuce was obtained by using eco-friendly organic fertilizer followed by commercial fertilizer than control one. The average maximum number of leaves, root length and yield per plot were observed by using cow dung in T₆, while the lowest in T₀. The chicken litter fertilized Plants had relatively higher average leaves length, leaves breadth and base diameter, while the maximum dry matter content and yield per hectare were found by applying cow dung in T₅. The highest gross return of BDT 1168800/ha and net return of BDT 683229/ha with the benefit cost ratio of 1.40 was obtained from T₅. From the economic point of view, it is concluded that T₅ was the best dose of fertilizer for maximizing the growth and yield of lettuce.

CHAPTER III

MATERIALS AND METHODS

This chapter presents a brief description about the research work. Here, experimental period, site description, climatic condition, crop or Planting materials, treatments, experimental design and layout, crop growing procedure, intercultural operations, data collection and statistical analysis are discussed. The details of experiments and methods are described below:

3.1 Experimental period

The experiment was conducted during the period from December 11, 2023, to March 15, 2024, in Rabi season.

3.2 Description of the study Site

3.2.1 Geographical location

Dinajpur district is in the Northern part of Bangladesh. The experimental site was selected in a moringa orchard existing on the Agroforestry and environment Research farm, Hajee Mohammad Danesh Science and Technology University, Dinajpur. The geographical location of the site was between 25°13' N latitude and 88°23' longitude and about 37.5 m above the sea level.

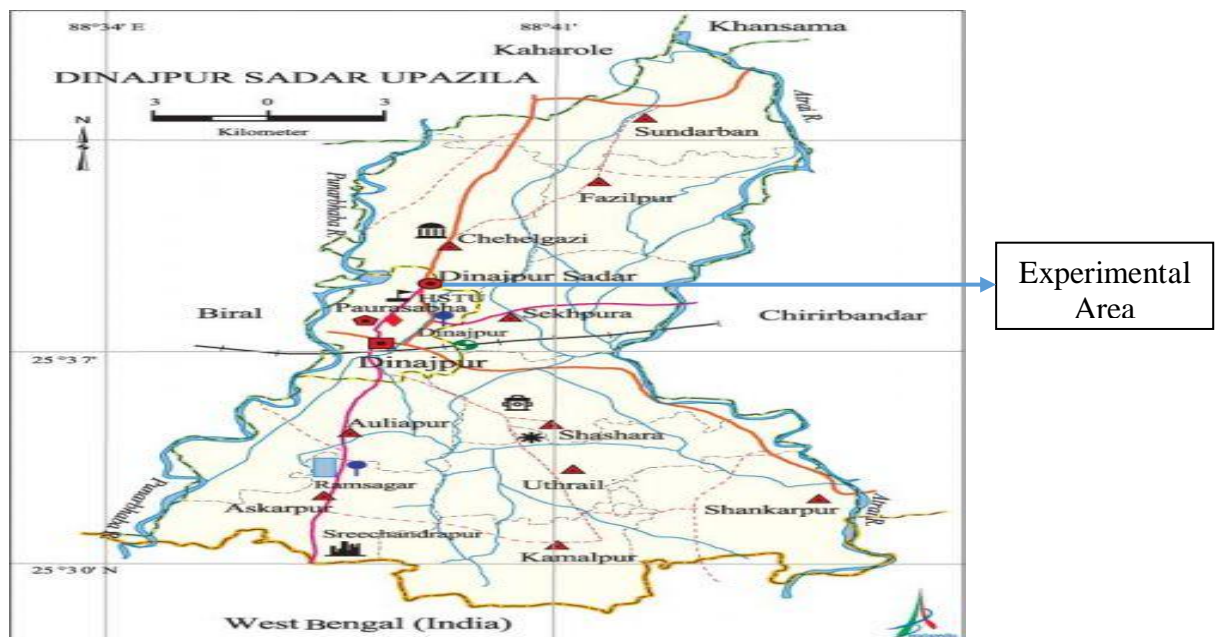


Figure 3.1: Map of HSTU under Dinajpur District

(Source: https://www.google.com/url?sa=i&url=https%3A%2F%2Fen.banglapedia.org%2Findex.php%2FDinajpur_Sadar_Upazila)

3.2.2 Soil Characteristics

The experimental plot was situated in a medium high land belonging to the Old Himalayan Piedmont Plain Area (AEZ 01). The land was well-drained as drainage system was well developed. The soil texture was sandy loam in nature. The soil pH was 5.35. The details of soil characteristics are presented in APPENDIX-I.

3.2.3 Climate of the experimental site

The climate of the site was tropical with heavy rainfall from July to August and scanty rainfall in the rest period of the year. Monthly maximum and minimum temperatures, rainfall and relative humidity recorded during the experimental period (November 2021 to March 2022) are included in APPENDIX-II.

3.3 Details of the Experimental methods

3.3.1 Experimental treatments

The experiment consisted of two factors i.e., Production systems and fertilizer applications. The treatments were as follows:

i) Factor A: Production Systems (2)

S₁= Lettuce as sole cropping (Open condition as control)

S₂=Lettuce + Moringa based agroforestry practice (Agroforestry system)

ii) Factor B: Fertilizer application packages (4)

F₁= (Chemical fertilizer) – FRG.2014, (Low fertility consider)

F₂= (Cow dung)–10 t ha⁻¹

F₃= (Poultry manure) –5 t ha⁻¹

F₄= (No fertilizer) – 0 t ha⁻¹

So, the treatment combinations are as:

S₁F₁, S₁F₂, S₁F₃, S₁F₄,

S₂F₁, S₂F₂, S₂F₃, S₂F₄.

Where,

S_1F_1 = (Sole cropping of Lettuce + Chemical fertilizer),

S_1F_2 = (Sole cropping of Lettuce + Cow dung),

S_1F_3 = (Sole cropping of Lettuce + Poultry manure),

S_1F_4 = (Sole cropping of Lettuce + No fertilizer),

S_2F_1 = (Lettuce + Moringa based agroforestry practice + Chemical fertilizer),

S_2F_2 = (Lettuce + Moringa based agroforestry practice + Cow dung),

S_2F_3 = (Lettuce + Moringa based agroforestry practice + Poultry manure),

S_2F_4 = (Lettuce + Moringa based agroforestry practice + No fertilizer).

Replication = 03

Total plot = $2 \times 4 \times 3 = 24$;

Plot size for understory lettuce Plant = $40\text{m} \times 25\text{cm}$

3.3.2. Structural Description of the Moringa Plant

Local name	: Sojna
Scientific name	: <i>Moringa oleifera</i>
Family	: Moringaceae
Planting orientation	: North-South
Moringa variety	: Baromasi
Age of moringa tree	: 6 years
Spacing	: $4\text{m} \times 4\text{m}$

Main characteristics

Moringa oleifera Plant belonging to family moringaceae and it is native to sub-Himalayan tracts of India, Pakistan, Bangladesh, and Afghanistan. It is a small, fast growing, evergreen or deciduous tree. *Moringa oleifera* is a small fast-growing evergreen or deciduous tree usually grows up to 10 or 12 m in height. It has spreading, fragile branches, feathery foliage of tri-pinnate leaves, and whitish gray bark. The leaves are bi-pinnate or commonly tri-pinnate up to 45 cm long the leaflets are hairy, green and

almost hairless on the upper surface. The twigs are hairy and green, these are compound leaves with leaflets of 1-2 cm long. The fragrant, bisexual, yellowish white flowers are hairy stalks in spreading or drooping axillary panicles 10-25 cm long. Individual flowers are approximately 0.7 to 1 cm long and 2 cm broad and five unequal yellowish white, thinly veined, spatulate petals, five stamens with five smaller sterile stamens and pistil composed of a 1-celled ovary and slender style. Fruits are tri-lobed capsules and are referred to pods it is pendulous, brown



Figure 3.2: Preparation of the field according to experimental design

triangular, and splits into three parts lengthwise when dry 30-120 cm long, 1.8 cm wide fruits production mostly occurs in March and April. Fruit contains around 26 seeds during their development stage. Immature pods are green in color they turn brown on maturity. Seeds are round 1cm in diameter with brownish semi-permeable seed hull with 3 papery wings hulls of seed are brown to black but can be white if kernels are of low viability. Viable seed germinate within 2 weeks; each tree can produce around 15,000 to 25,000 seeds/year. Average weight is 0.3 gm/seed (Foidl *et al.* 2001).

3.3.3 Experimental design

Experiment was laid out following a two factorial Randomized Complete Block Design (RCBD) with 3 replications, each replication contains 8 plots. The experimental site was 200m² area. Total number of experimental plots was 24 and the sizes of each unit plot was 3m×2m = 6m².

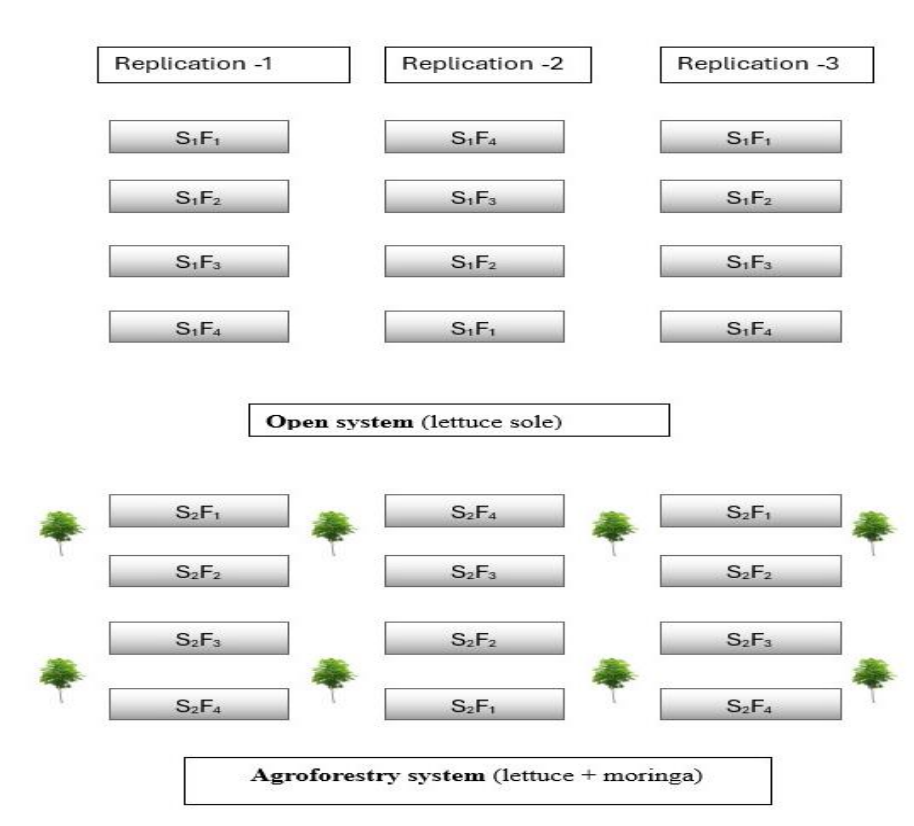


Figure 3.3: Layout of the experimental field

Note: Two Lettuce systems are S₁ (Lettuce sole), S₂ (Lettuce + Moringa), four fertilizer packages are F₁ (Chemical fertilizer), F₂ (Cow dung), F₃ (Poultry Manure) and F₄ (No Fertilizer).

3.3.4 Planting material

The Planting materials comprised the certified seed of “BARI Lettuce -1” with two production systems. The production systems were:

S₁=Lettuce sole

S₂=Lettuce with Moringa based agroforestry practice

3.5 Crop management

3.5.1 Collection of seed

Seeds were collected from Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh.



Figure 3.4: Collection of seeds

3.5.2 Preparation of seedling

The seeds of “BARI Lettuce-1” were used as Planting material. At first, the seeds were Planted in the definite small field. Healthy seedling were selected as seed for the good germination and growth of the Lettuce Plants.



Figure 3.5: Preparation of seeds

3.5.3 Soil preparation

Weeds and Stubbles were completely cleaned from the experimental site. The land was ploughed and leveled properly before Planting. The land was ploughed 2 times by a

power tiller to make the soil fine tillage. Then the field layout was made as per experimental design. All basal dosages of fertilizers as per requirement were incorporated in the soil such as Chemical fertilizer (Urea, TSP, MOP, and Gypsum), cow dung, poultry manure and no fertilizer on December 26, 2023. After applying fertilizer, the plots were given rest for 1 week. Finally the plots were made ready for sowing the seedling of lettuce on January 4, 2024. Total 1440 seedlings were sowing in two systems.



Figure 3.6: Soil preparation before Planting

12 seedlings were sowing for each line in every plot. There were 5 lines in every plot. So, for 5 line ($5 \times 12 = 60$) seedlings and for 24 plots ($24 \times 60 = 1440$) seedlings, total 1440 number of seedlings were sowing in two systems. After sowing, the plots were watered both systems.

3.5.4 Fertilizer applications

The experimental soil was fertilized with following dose of Urea, Triple Super Phosphate (TSP), Murat of Potash (MOP), Gypsum, Cow dung in fully chemically fertilized for 6 plots named F_1 .

Fertilizers	Doses
Urea	720g
TSP	432g
MOP	216g
Gypsum	300g
Cow dung	54kg
Poultry manure	18kg

Source: (FRG.2014), (Low fertility consider)

But, The Cow dung also needed for another 6 plots named F₂ and Poultry manure also needed for another 6 plots named F₃. The entire amounts of TSP, MOP, Gypsum, Cow dung and Poultry manure were applied as basal dose at 7 days before sowing. For Urea, Rest of the urea was applied after one month after sowing as per treatment.



Figure 3.7: Fertilizer application

3.5.5 Intercultural operations

3.5.5.1 Weeding

Weeding was necessary to keep the Plant free from weeds. The newly emerged weeds were uprooted carefully from the field after complete emergence of sprouts and afterwards when necessary. Three times weeding was done during the crop season.



Figure 3.8: Weeding

3.5.5.2 Watering

Two times irrigation was done in the field to keep upon moisture status of soil retained as requirement of Plants. Excess water was not given, because it always harmful for lettuce plan.



Figure 3.9: Watering

3.5.5.3 Earthing up

Earthing up process was done by pouring the soil in the base of the Plant at three times, during crop growing period. First pouring was done at 20 days after sowing and second was at 35 DAS and third one at 60 DAS and fourth one 75 DAS.

3.5.5.4 Plant protection measures

Dithane M-45 was applied at 30 DAP as a preventive measure for controlling fungal infection, e.g. purple blotch, leaf curl virus. Also, Redomil @ 2 ml liter⁻¹ of water at 7 days interval was applied for virus affected Plants.

3.5.5.5 Harvesting of Lettuce

Harvesting of lettuce was done at 60 DAS on 5 March, 2024. The lettuce Plant of each plot were separately harvested, bagged and tagged and brought to the laboratory. The yield of lettuce plot⁻¹ was determined in kg. Harvesting was done manually by hand. Harvesting was done within 2 times at 60 DAS and 70 DAS.



Figure 3.10: Harvesting of lettuce

3.6. Recording of data

The experimental plots were supervised frequently to record changes in Plant characteristics at different stages of their growth. Experimental data were recorded at 45 DAS, 60 DAS for Raw data and at 60 DAS and 70 DAS for harvesting data and after harvest yield characters and quality characters were recorded. Ten Plants were selected randomly from each unit plot to record required experimental data. The observations were taken sincerely according to treatment combinations for the experiment. Temperature In ($^{\circ}\text{C}$), Temperature out ($^{\circ}\text{C}$), Relative Humidity (RH %) and Light Intensity (Klux) of the experiment field was recorded during the growing period of lettuce. Leaves number and weight of leaves (g) were recorded during the harvesting period of lettuce.



Figure 3.11: Recording of data

A. Parameters for raw data for Plant growth characters

- i.** Plant height at 45 and 60 DAS
- ii.** Number of leaves Plants at 45 and 60 DAS
- iii.** Leaves Length at 45 and 60 DAS
- iv.** Leaves Breadth at 45 and 60 DAS
- v.** Leaves Length and Breadth ratio at 45 and 60 DAS

B. Parameters for harvesting data for Plants yield and yield components

- i.** Numbers of leaves Plant⁻¹ at 60 DAS and 70 DAS
- ii.** Number of leaves Plot⁻¹ at 60 DAS and 70 DAS
- iii.** Leaves weight Plant⁻¹ (g) at 60 DAS and 70 DAS
- iv.** Weight of lettuce Plot⁻¹ (g) at 60 DAS and 70 DAS
- v.** Weight of lettuce Plot⁻¹ (kg), or (Yield of lettuce Plot⁻¹) (kg)
- vi.** Yield of lettuce Plot⁻¹ (t ha⁻¹)
- vii.** Dry weight (gm.)

C. Quality characters

- i.** % Moisture
- ii.** % Dry matter
- iii.** % Protein
- iv.** % Ash
- v.** Chlorophyll_a mg g⁻¹ (Fresh leaf)
- vi.** Chlorophyll_b mg g⁻¹ (Fresh leaf)
- vii.** Carotene mg g⁻¹ (Fresh leaf)
- viii.** Ca mg 100g⁻¹ (Fresh leaf)
- ix.** Mg mg 100g⁻¹ (Fresh leaf)
- x.** Na mg 100g⁻¹ (Fresh leaf)

- xi.** K mg 100g⁻¹ (Fresh leaf)
- xii.** S mg 100g⁻¹ (Fresh leaf)
- xiii.** P mg 100g⁻¹ (Fresh leaf)
- xiv.** Temperature In (°c)
- xv.** Temperature Out (°c)
- xvi.** Relative Humidity (RH %)

3.7 Experimental measurements

A brief outline of the data recording procedure followed during the study is given below:

Plant height (cm): The average length of the Plant in cm was measured from the soil surface to the tip of ten randomly taken Plants in each plot at different physiological stage (at 45 DAS and 60 DAS).

Leaf number per Plant: The total number of healthy leaves was counted from the ten randomly taken Plants at the time of physiological maturity stages (at 45 DAS and 60 DAS) from each experimental unit according to treatment combination.

Leaf length: The average length of leaf, at physiological maturity was measured in cm from the ten randomly taken Plants. Three leaves from each sample Plant were measured for averaging the length of the leaf at the time of physiological maturity stages (at 45 DAS and 60 DAS).

Leaf breadth: The average width of leaves was recorded from ten randomly taken Plants in each unit of plots. Three leafs from each sample Plant was measured at the widest part at the time of physiological maturity stages (at 45 DAS and 60 DAS).

Leaf Length and Leaf Breadth Ratio: The average length of leaves and breadth of leaves were recorded from ten randomly taken Plants in each unit of plots. Three leafs from each sample Plant were measured for averaging the length of the leaf and three leafs from each sample Plant were measured at the widest part at the time of physiological maturity stages (at 45 DAS and 60 DAS).

Numbers of leaves Plant⁻¹: The total number of healthy leaves was harvested from the ten randomly taken Plants from each experimental unit of plots according to treatment combination within 2 times of physiological maturity stages (at 60 DAS and 70 DAS).

Number of leaves Plot⁻¹: The total number of healthy leaves was harvested from the ten randomly taken Plants from each experimental unit of plots according to treatment combination (at 60 DAS and 70 DAS).

Leaves weight Plant⁻¹ (gm.): The average mature leave weight (gm.) per Plant was recorded after weighting ten leaves produced in the three central rows and dividing by the number of Plants at the time of physiological maturity stages (at 60 DAS and 70 DAS).

Weight of lettuce Plot⁻¹ (gm.): The average mature leave weight (gm.) per plot was recorded after weighting ten leaves produced in the three central rows and dividing by the number of Plants.

Weight of lettuce / plot (kg), or (Yield of lettuce / plot) (kg): The average mature leave weight (kg.) per plot was recorded after weighting ten leaves produced in the three central rows and dividing by the number of Plants. This is called the yield of lettuce.

Yield of lettuce (t ha⁻¹): Total leaves yield of Plants grown in each experimental unit of plot was recorded. Then according to treatment combination the yields obtained from plots were converted to hectare base.

Dry weight (gm.): The samples of leaves were collected 100 gm. from each treatment of plots. After that, the samples were dried in oven at 65⁰C for 72 hours. From which the weights of lettuce dry (gm.) were recorded.



Figure 3.12: Dry weight (g)

Percentage of moisture: The samples of leaves were collected from each treatment. From which the (% Moisture) of lettuce were recorded in the laboratory.

Percentage of dry matter: The samples of leaves were collected from each treatment. After that, the samples were dried in oven at 65⁰C for 72 hours. From which the weights of lettuce dry matter content (%) were recorded in the laboratory.

Percentage of protein: The samples of leaves were collected from each treatment. From which the (% protein) of lettuce were recorded.

Percentage of ash: The oven dried leaves were further dried in a muffle furnace at 600⁰C for two hours. Ash % was calculated for each treatment combination.



Figure 3.13: Muffle Furnace

Chlorophyll a mg g⁻¹ (Fresh leaf): The samples of fresh leaves were collected from each treatment of plots. From which the Chlorophyll a mg g⁻¹ (Fresh leaf) of lettuce were recorded in the chemistry laboratory.

Chlorophyll b mg g⁻¹ (Fresh leaf): The samples of fresh leaves were collected from each treatment of plots. From which the Chlorophyll b mg g⁻¹ (Fresh leaf) of lettuce were recorded in the chemistry laboratory.

Carotene mg g⁻¹ (Fresh leaf): The samples of fresh leaves were collected from each treatment of plots. From which the Carotene mg g⁻¹ (Fresh leaf) of lettuce were recorded in the chemistry laboratory.

Ca mg 100g⁻¹ (Fresh leaf): The samples of fresh leaves were collected from each treatment of plots. From which the Ca mg g⁻¹ (Fresh leaf) of lettuce were recorded in the chemistry laboratory.

Mg mg 100g⁻¹ (Fresh leaf): The samples of fresh leaves were collected from each treatment of plots. From which the Mg mg g⁻¹ (Fresh leaf) of lettuce were recorded in the chemistry laboratory.

Na mg 100g⁻¹ (Fresh leaf): The samples of fresh leaves were collected from each treatment of plots. From which the Na mg g⁻¹ (Fresh leaf) of lettuce were recorded in the chemistry laboratory.

K mg 100g⁻¹ (Fresh leaf): The samples of fresh leaves were collected from each treatment of plots. From which the K mg g⁻¹ (Fresh leaf) of lettuce were recorded in the chemistry laboratory.

S mg 100g⁻¹ (Fresh leaf): The samples of fresh leaves were collected from each treatment of plots. From which the S mg g⁻¹ (Fresh leaf) of lettuce were recorded in the chemistry laboratory.

P mg 100g⁻¹ (Fresh leaf): The samples of fresh leaves were collected from each treatment of plots. From which the P mg g⁻¹ (Fresh leaf) of lettuce were recorded in the chemistry laboratory.

Temperature in (°c): The temperatures were measured from each treatment of plots. From which the temperature in (°c) were recorded in the plots.

Temperature out (°c): The temperatures were measured from each treatment of plots. From which the temperature out (°c) were recorded in the plots.

Relative Humidity (RH %): The relative humidity (RH) were measured from each treatment of plots. From which the relative humidity (%) were recorded in the plots.

Light intensity (klux): Light Intensity was measured on randomly selected experimental plots from the moringa tree base to lettuce plots at three distances throughout the cropping season. The device Light Meter (CEM DT-1308) was used to measure light intensity in klux to determine how much the shading effect of moringa tree differ from open field.



Figure 3.14: Light intensity measuring device.

3.8 Economic Analysis

3.8.1 Total Cost of Production

The cost of cultivation of the moringa tree was worked out on the basis of per hectare. The initial Plantation cost of moringa sapling and management cost was included. Lettuce production cost was added with moringa to calculate total cost of production. The total cost included the cost items like human labor and mechanical power costs, material cost (including cost of seeds, fertilizers, pesticides, irrigation, bamboos, ropes, etc.), land use cost, interest on operating capital and miscellaneous cost.

3.8.2 Gross Return

Gross return is the monetary value of total product and by-product. Per hectare gross returns from lettuce and moringa was calculated by multiplying the total amount of production by their respective market prices.

3.8.3 Net Return

It is the profit from the entire production. Net return was calculated by subtracting the total costs from gross field benefits for each treatment.

$$\text{Net Return} = \text{Gross return (tk/ha)} - \text{total cost of production (tk/ha)}$$

3.8.4 Benefit-Cost Ratio (BCR)

It is the ratio of gross return with the total cost of production. BCR gives idea whether a production system will be beneficial to farmers or not.

$$\text{BCR} = \text{Gross Return (tk/ha)} / \text{Total Cost of Production}$$

3.9 Statistical Analysis

The experiment was conducted by RCBD design, and the experimental data recorded for different characters were statistically used following “Analysis of variance” (ANOVA) technique with the help of statistix 10 (analysis software). The mean differences were adjudged by Tukey HSD test. Least significant differences at 5% level of probability were computed to delineate the significances between the treatment means.

CHAPTER IV

RESULTS AND DISCUSSION

In this chapter the result of the screening of two lettuce systems and four fertilizer applications under moringa based agroforestry system are presented in tables and graphs. Moreover, the findings of the study and interception of the results under different critical sections comprising growth, yield, quality parameters and economic analysis are also presented and discussed in this chapter under following heads:

4.1 Plant Growth Characters

4.1.1 Plant Height (cm) Plant⁻¹

4.1.1.1 Effect of production systems

The results presented in Table-4.1 revealed significant differences between the lettuce production system concerning Plant height (cm) at different days after sowing (DAS) i.e. 45 DAS and 60 DAS. At 45 DAS, the highest Plant height (26.10 cm) was recorded from S₂ treatment (Lettuce + Moringa based agroforestry system), whereas the lowest Plant height (14.47 cm) was observed in S₁ treatment (Lettuce sole). Similarly, at 60 DAS, S₂ also displayed the same trend, and the highest Plant height (30.39 cm) was obtained from S₂ treatment. On the other hand, S₁ gave the lowest Plant height (19.05 cm).

The findings of this study highlight significant variations in Plant height between the two lettuce production systems evaluated. S₂ (Lettuce+ Moringa) consistently exhibited superior growth in terms of Plant height compared to S₁ (Lettuce sole) production system throughout the entire growth period. These differences in Plant height can be attributed to systematic characteristics and physiological processes specific to each system. Moreover, the results suggest that Plant height is influenced by environmental conditions. As demonstrated by the consistent trend of Plant height at different time points, the effect of production system played a crucial role in determining the growth performance of lettuce. The observed variations in Plant height have practical implications for lettuce cultivation. Farmers should consider these differences while selecting appropriate lettuce production systems for specific agro-climatic regions and desired yield outcomes.

Table-4.1: Effect of Production Systems on Plant Height

Treatments (Production Systems)	Plant height (cm) Plant⁻¹	
	45 DAS	60 DAS
S ₁	14.47 b	19.05 b
S ₂	26.10 a	30.39 a
CV (%)	8.09	6.61

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Note: S₁ (Lettuce sole), S₂ (Lettuce + Moringa)

4.1.1.2 Fertilizer Effect

Under the different lettuce production systems, table-4.2 presents the Plant height measurements at two different time points (at 45 DAS and 60 DAS) for each fertilizer treatment. At 45 DAS, the highest Plant height (21.91 cm) was observed in Plants treated with F₁ (Chemical fertilizer), while the lowest Plant height (19.06 cm) was recorded in Plants treated with F₄ (No fertilizer). Similarly, at 60 DAS, the highest Plant height (26.55 cm) was achieved with F₁ (Chemical fertilizer) treatment, while the lowest Plant height (22.91 cm) was seen in Plants treated with F₄ (No fertilizer). So, it is said that the Plants treated with fully chemical fertilizer exhibited the highest Plant height, whereas the Plants treated with no fertilizer displayed the lowest Plant height.

The outcomes of the study suggested that chemical fertilizer application led to higher Plant growth compared to organic fertilizer applications. This difference can be attributed to the readily available nutrients present in chemical fertilizers, which are easily absorbed and utilized by Plants, promoting their growth and development.

4.1.1.3 Interaction Effect

The analysis of variance revealed that Plant height was significantly influenced by the production systems and fertilizer applications (Table-4.3). In case of the interaction effect at 45 DAS, the highest Plant height (27.68 cm) was obtained from the treatment S₂F₁ (Lettuce with Moringa + Chemical fertilizer), and the lowest Plant height (13.55 cm) was found from the treatment S₁F₄ (Lettuce sole + No fertilizer). Again at 60 DAS, the highest Plant height (31.80 cm) was measured from the treatment S₂F₃ (Lettuce with Moringa + Poultry manuring) and the lowest Plant height (17.48 cm) was found from the

treatment S₁F₄ (Lettuce sole + No fertilizer). So, It is said that the highest Plant height was measured from the treatment S₂F₃ (Lettuce with Moringa + Poultry manuring) and the lowest Plant height was found from the treatment S₁F₄ (Lettuce sole + No fertilizer). The results of the study indicated that both production systems and fertilizer applications play crucial roles in determining the Plant height of lettuce Plants. The higher Plant height in the treatment S₂F₁, where Lettuce with Moringa was combined with Chemical fertilizer, indicates that this system responds positively to chemical fertilizers. On the other hand, the lower Plant height in the treatment S₁F₄, where Lettuce sole was not provided with any fertilizer, suggests that this system may require external nutrient supplementation to reach its maximum growth potential. The increase in Plant height over time (from 45 DAS and 60 DAS) is expected, as it reflects the normal growth pattern of Plants. However, the variations in height at different growth stages due to the interaction effect indicate that the influence of fertilizer applications on Plant height is dynamic and changes as the Plant develops.

Table-4.2: Effect of Fertilizer Applications on Plant Height

Treatments (Fertilizers)	Plant height (cm) Plant⁻¹	
	45 DAS	60 DAS
F ₁	21.91 a	26.55 a
F ₂	19.77 ab	24.33 ab
F ₃	20.40 ab	25.10 ab
F ₄	19.06 b	22.91 b
CV (%)	8.09	6.61

In a column, figures having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Note: F₁ (Chemical fertilizer), F₂ (Cow dung), F₃ (Poultry manure) and F₄ (No fertilizer).

Table-4.3: Interaction Effect of Production Systems and Fertilizer Applications on Plant Height

Production Systems × Fertilizer applications	Effect of Plant Height(cm) Plant ⁻¹	
	45 DAS	60 DAS
S ₁ F ₁	16.13 b	21.46 b
S ₁ F ₂	14.28 b	18.87 b
S ₁ F ₃	13.90 b	18.40 b
S ₁ F ₄	13.55 b	17.48 b
S ₂ F ₁	27.68 a	31.63 a
S ₂ F ₂	25.25 a	29.80 a
S ₂ F ₃	26.90 a	31.80 a
S ₂ F ₄	24.57 a	28.33 a
CV (%)	8.09	6.61

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where, S₁F₁=(Lettuce sole + Chemical fertilizer),S₁F₂=(Lettuce sole + Cow dung),S₁F₃=(Lettuce sole + Poultry manure),S₁F₄ =(Lettuce sole + No fertilizer),S₂F₁ =(Lettuce with Moringa + Chemical fertilizer),S₂F₂ = (Lettuce with Moringa + Cow dung),S₂F₃ =(Lettuce with Moringa + Poultry manure), S₂F₄=(Lettuce with Moringa + No fertilizer).

4.1.2 Number of Leaves Plant⁻¹

4.1.2.1 Effect of Production Systems

The present study aimed to investigate the variation in the number of leaves per Plant between two systems of a Plant species, with data collected at two different time points after sowing i.e. 45 DAS and 60 DAS. The results, as summarized in Table-4.4, demonstrated significant differences in the number of leaves per Plant across the systems at all two time points. At 45 DAS, the highest number of leaves (20.33) was recorded from S₂ treatment (Lettuce + Moringa based agroforestry system), whereas the lowest number of leaves (13.82) was observed in S₁ treatment (Lettuce sole). Similarly, at 60

DAS, S₂ also displayed the same trend, and the highest number of leaves (24.13). On the other hand, S₁ gave the lowest leaves number (18.01).

The findings of this study highlight significant variations in leaves number between the two lettuce production systems evaluated. S₂ (Lettuce+ Moringa) consistently exhibited superior growth in terms of leaves number compared to S₁ (Lettuce sole) production system throughout the entire growth period. The observed variations in leaves number have practical implications for lettuce cultivation. Farmers should consider these differences while selecting appropriate lettuce production systems for specific agro-climatic regions and desired yield outcomes.

Table-4.4: Effect of Production Systems on Number of Leaves Plant⁻¹

Treatments (Production Systems)	Number of Leaves Plant ⁻¹	
	45 DAS	60 DAS
S ₁	13.82 b	18.01 b
S ₂	20.33 a	24.13 a
CV%	10.57%	9.24%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter (s) differ significantly.

Note: S₁ (Lettuce sole), S₂ (Lettuce with Moringa)

4.1.2.2 Fertilizer effect

The results of the study indicated at Table-4.5 showed that there were no significant differences in the number of leaves per Plant at different fertilizer applications under the moringa-based agroforestry system. However, there were some variations observed in the number of leaves per Plant at different stages of the Plant's growth (45 DAS and 60 DAS). At 45 DAS, the highest number of leaves per Plant (19.72) was recorded in the treatment where chemical fertilizer (F₁) was applied, while the lowest number of leaves per Plant (15.30) was observed in the treatment where no fertilizer (F₄) was applied. At 60 DAS, the highest number of leaves per Plant (23.70) was found in the treatment with chemical fertilizer (F₁), and the lowest number of leaves per Plant (18.95) was found in the treatment with no fertilizer (F₄). So, It id said that the highest number of leaves per

Plant was recorded in the treatment with chemical fertilizer (F_1), whereas the lowest number of leaves per Plant was observed in the treatment with no fertilizer (F_4).

The results suggest that, overall, the application of chemical fertilizer led to higher Plant growth in terms of the number of leaves per Plant compared to the organic fertilizer treatments. This difference is attributed to the readily available nutrients in chemical fertilizers, which are more easily absorbed by the Plants, promoting faster growth.

Table-4.5: Effect of Fertilizer Applications on Number of Leaves Plant⁻¹

Treatments (Fertilizers)	Number of Leaves Plant ⁻¹	
	45 DAS	60 DAS
F_1	19.72 a	23.70 a
F_2	16.35 b	20.35 b
F_3	16.93 ab	21.27 ab
F_4	15.30 b	18.95 b
CV (%)	10.57%	9.24%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Note: F_1 (Chemical fertilizer), F_2 (Cow dung), F_3 (Poultry manure) and F_4 (No fertilizer).

4.1.2.3 Interaction Effect

The variations of number of leaves Plant⁻¹ due to the interaction effect of production systems and fertilizer applications were found significant in all the growth stages (Table-4.6). At 45 DAS, the treatment S_2F_1 , which involved using the system "Lettuce with Moringa" along with chemical fertilizer, exhibited the highest number of leaves per Plant (23.50). On the other hand, the treatment S_1F_3 , which used the system "Lettuce sole" with poultry manuring, showed the lowest number of leaves per Plant (12.30). Similarly, at 60 DAS, the treatment S_2F_1 had the highest number of leaves per Plant (27.07) when "Lettuce with Moringa" was combined with chemical fertilizer. Conversely, the treatment S_1F_3 had the lowest number of leaves per Plant (16.97) when "Lettuce sole" was used with poultry manuring. So, It is said that the treatment S_2F_1 demonstrated the highest number of leaves per Plant with the combination of "Lettuce with Moringa" and

chemical fertilizer. On the other hand, the treatment S₁F₃ had the lowest number of leaves per Plant when "Lettuce sole" was used with poultry manure fertilizer.

Table-4.6: Interaction Effect of Production Systems and Fertilizer Applications on Number of Leaves Plant⁻¹

Production Systems × Fertilizer applications	Number of Leaves Plant ⁻¹	
	45 DAS	60 DAS
S ₁ F ₁	15.93 cd	20.33 bc
S ₁ F ₂	13.50 d	17.47 c
S ₁ F ₃	12.30 d	16.97 c
S ₁ F ₄	13.53 d	17.27 c
S ₂ F ₁	23.50 a	27.07 a
S ₂ F ₂	19.20 abc	23.23 ab
S ₂ F ₃	21.57 ab	25.57 ab
S ₂ F ₄	17.04 bcd	20.63 bc

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where, S₁F₁=(Lettuce sole + Chemical fertilizer),S₁F₂=(Lettuce sole + Cow dung),S₁F₃=(Lettuce sole + Poultry manure),S₁F₄ =(Lettuce sole + No fertilizer),S₂F₁ =(Lettuce with Moringa + Chemical fertilizer),S₂F₂ = (Lettuce with Moringa + Cow dung),S₂F₃ =(Lettuce with Moringa + Poultry manure), S₂F₄=(Lettuce with Moringa + No fertilizer).

4.1.3 Leaf Length (cm) Plant⁻¹

4.1.3.1 Effect of Production Systems

Leaf is a food manufacturing factory for Plants. Leaf area (leaf length × leaf breadth) is directly related to photosynthesis as it provides more area for photosynthetic activity which consequently affects the yield. The photosynthetic material synthesized in the leaves primarily flows down to the root zone for leaf formation. Leaf length of lettuce was significantly varied (Table-4.7) due to the effect of production system, at 45 DAS,

the highest leaf length (21.40 cm) was found from S₂ which was followed by (Lettuce with Moringa), whereas the lowest leaf length (13.07 cm) was from S₁ (Lettuce sole). At 60 DAS, the highest leaf length (22.12 cm) was recorded from S₂ (Lettuce with Moringa) while the lowest leaf length (13.90 cm) was observed from S₁ (Lettuce sole). So, It is said that the highest leaf length was recorded from S₂ (Lettuce with Moringa) while the lowest leaf length was similarly from S₁ (Lettuce sole).

Table-4.7: Effect of Production Systems on Leaf Length (cm) Plant⁻¹

Treatments (Production Systems)	Leaf Length (cm) Plant ⁻¹	
	45 DAS	60 DAS
S ₁	13.07 b	13.90 b
S ₂	21.40 a	22.12 a
CV%	8.96%	8.60%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Note: S₁ (Lettuce sole), S₂ (Lettuce with Moringa)

4.1.3.2 Fertilizer effect

Under the different lettuce production systems, (Table-4.8) presents the leave length measurements at two different time points (at 45 DAS and 60 DAS) for each fertilizer treatment revealed that at 45 days after sowing (DAS), the highest leaf length of (19.11 cm) was observed in the Plants treated with chemical fertilizer (F₁), while the lowest leaf length of (15.40 cm) was recorded in the Plants with no fertilizer application (F₄). This suggests that chemical fertilizer positively influenced early leaf growth compared to the absence of fertilizers. Similarly, at 60 DAS, the highest leaf length of (20.09 cm) was again found in the Plants treated with chemical fertilizer (F₁), and the lowest leaf length of (16.15 cm) was found in the non-fertilized Plants (F₄). As the Plants progressed, the differences in leaf length became more prominent. The Plants treated with chemical fertilizer (F₁) exhibited the highest leaf length, while the non-fertilized Plants (F₄) had the lowest leaf length. These results indicate that the positive effect of chemical fertilizer on leaf growth was sustained over the entire growth period, leading to significantly longer leaves compared to the absence of fertilizers.

Table-4.8: Effect of Fertilizer Applications on Leaf Length (cm) Plant⁻¹

Treatments (Fertilizers)	Leaf Length (cm) Plant ⁻¹	
	45 DAS	60 DAS
F ₁	19.11 a	20.09 a
F ₂	16.80 ab	17.54 ab
F ₃	17.62 ab	18.27 ab
F ₄	15.40 b	16.15 b
CV (%)	8.96%	8.60%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Note: F₁ (Chemical fertilizer), F₂ (Cow dung), F₃ (Poultry manure) and F₄ (No fertilizer).

4.1.3.3 Interaction effect

The results of the analysis of variance (ANOVA) presented in (Table-4.9) demonstrate that leaf length in lettuce Plants is significantly influenced by the interaction between the production systems of lettuce and the type of fertilizer application. At 45 DAS, the treatment S₂F₁, which involved the lettuce system "Lettuce with Moringa" and the application of a chemical fertilizer, resulted in the highest leaf length of (23.47 cm). On the other hand, the treatment S₁F₄, which utilized "Lettuce sole" without any fertilizer application, showed the lowest leaf length of (12 cm). This substantial difference in leaf length between the two treatments highlights the importance of choosing the right production system and utilizing appropriate fertilizers to enhance leaf development during the early growth stage of lettuce Plants.

As the Plants progressed to 60 DAS, the treatment S₂F₁ (Lettuce with Moringa + Chemical fertilizer) continued to demonstrate superior performance with a leaf length of (24.32 cm). Conversely, the treatment S₁F₄ (Lettuce sole + No fertilizer) still exhibited the lowest leaf length, albeit with a slight increase to (12.74 cm). This substantial difference in leaf length at the later growth stage emphasizes the cumulative effect of production system-fertilizer interactions on the overall growth and development of lettuce Plants.

Table-4.9: Interaction Effect of Production Systems and Fertilizer Applications on Leaf Length (cm) Plant⁻¹

Production Systems × Fertilizer applications	Effect of Leaf Length (cm) Plant ⁻¹	
	45 DAS	60 DAS
S ₁ F ₁	14.76 cd	15.86 cd
S ₁ F ₂	13.01 d	13.76 d
S ₁ F ₃	12.50 d	13.25 d
S ₁ F ₄	12 d	12.74 d
S ₂ F ₁	23.47 a	24.32 a
S ₂ F ₂	20.59 ab	21.31 ab
S ₂ F ₃	22.73 ab	23.30 ab
S ₂ F ₄	18.79 bc	19.56 bc
CV (%)	8.96%	8.60%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where, S₁F₁=(Lettuce sole + Chemical fertilizer),S₁F₂=(Lettuce sole + Cow dung),S₁F₃=(Lettuce sole + Poultry manure),S₁F₄ =(Lettuce sole + No fertilizer),S₂F₁ =(Lettuce with Moringa + Chemical fertilizer),S₂F₂ = (Lettuce with Moringa + Cow dung),S₂F₃ =(Lettuce with Moringa + Poultry manure), S₂F₄=(Lettuce with Moringa + No fertilizer).

4.1.4 Leaf Breadth (cm) Plant⁻¹

4.1.4.1 Effect of Production Systems

Leaf is a food manufacturing factory for Plants. Leaf area (leaf length × leaf breadth) is directly related to photosynthesis as it provides more area for photosynthetic activity which consequently affects the yield. Leaf breadth of lettuce was significantly varied (Table-4.10) because of production system. It was found from the experimental result that at 45 DAS, the highest leaf breadth (13.58 cm) was found from S₂ which was followed by (Lettuce with Moringa), whereas the lowest leaf length (10.26 cm) was from S₁ (Lettuce sole). At 60 DAS, the highest leaf breadth (14.41 cm) was recorded from S₂ (Lettuce with Moringa) while the lowest leaf length (10.72 cm) was observed from S₁ (Lettuce sole). The observed variations in leaf breadth between different lettuce production systems can be attributed to the effect of production system.

Table-4.10: Effect of Production Systems on Leaf Breadth (cm) Plant⁻¹

Treatments (Production Systems)	Leaf Breadth (cm) Plant ⁻¹	
	45 DAS	60 DAS
S ₁	10.26 b	10.72 b
S ₂	13.58 a	14.41 a
CV%	7.51%	7.84%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Note: S₁ (Lettuce sole), S₂ (Lettuce with Moringa)

4.1.4.2 Fertilizer effect

The systems had different leaf breadth at different fertilizer applications which might be due to the differences of the production systems. Under the different agroforestry production system the result (Table-4.11) revealed that At 45 days after sowing (DAS), the highest leaf breadth of (13.43 cm) was observed in the Plants treated with chemical fertilizer (F₁), while the lowest leaf length of (10.63 cm) was recorded in the Plants with no fertilizer application (F₄). This suggests that chemical fertilizer positively influenced early leaf growth compared to the absence of fertilizers. Similarly, at 60 DAS, the highest leaf length of (14.17 cm) was again found in the Plants treated with chemical fertilizer (F₁), and the lowest leaf breadth of (11.30 cm) was found in the non-fertilized Plants (F₄).

Table-4.11: Effect of Fertilizer Applications on Leaf Breadth (cm) Plant⁻¹

Treatments (Fertilizers)	Leaf Breadth (cm) Plant ⁻¹	
	45 DAS	60 DAS
F ₁	13.43 a	14.17 a
F ₂	11.45 bc	12.09 b
F ₃	12.19 ab	12.72 ab
F ₄	10.63 c	11.30 b
CV (%)	7.51 %	7.84 %

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Note: F₁ (Chemical fertilizer), F₂ (Cow dung), F₃ (Poultry manure) and F₄ (No fertilizer).

4.1.4.3 Interaction effect

The results of the analysis of variance (ANOVA) presented in (Table-4.12) demonstrate that leaf breadth in lettuce Plants is significantly influenced by the interaction between

the production systems of lettuce and the type of fertilizer application. At 45 DAS, the treatment S₂F₁, which involved the lettuce system "Lettuce with Moringa" and the application of a chemical fertilizer, resulted in the highest leaf breadth of (14.96 cm). On the other hand, the treatment S₁F₂, which utilized "Lettuce sole" with cow dung application, showed the lowest leaf breadth of (9.65 cm). This substantial difference in leaf breadth between the two treatments highlights the importance of choosing the right system and utilizing appropriate fertilizers to enhance leaf development during the early growth stage of lettuce Plants.

As the Plants progressed to 60 DAS, the treatment S₂F₁ (Lettuce with Moringa + Chemical fertilizer) continued to demonstrate superior performance with a leaf breadth of (15.65 cm). Conversely, the treatment S₁F₄ (Lettuce sole + No fertilizer) still exhibited the lowest leaf breadth, albeit with a slight increase to (9.81 cm). This substantial difference in leaf breadth at the later growth stage emphasizes the cumulative effect of production system-fertilizer interactions on the overall growth and development of lettuce Plants.

Table-4.12: Interaction Effect of Production Systems and Fertilizer Applications on Leaf Breadth (cm)/ Plant

Production Systems × Fertilizer applications	Effect of Leaf Breadth (cm) Plant ⁻¹	
	45 DAS	60 DAS
S ₁ F ₁	11.89 bc	12.68 bc
S ₁ F ₂	9.65 c	10.18 cd
S ₁ F ₃	9.84 c	10.21 cd
S ₁ F ₄	9.68 c	9.81 d
S ₂ F ₁	14.96 a	15.65 a
S ₂ F ₂	13.26 ab	13.99 ab
S ₂ F ₃	14.53 a	15.22 ab
S ₂ F ₄	11.57 bc	12.78 bc
CV (%)	7.51 %	7.84 %

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly

Where, S₁F₁=(Lettuce sole + Chemical fertilizer),S₁F₂=(Lettuce sole + Cow dung),S₁F₃=(Lettuce sole + Poultry manure),S₁F₄ =(Lettuce sole + No fertilizer),S₂F₁ =(Lettuce with Moringa + Chemical fertilizer),S₂F₂ =(Lettuce with Moringa + Cow dung),S₂F₃=(Lettuce with Moringa + Poultry manure), S₂F₄=(Lettuce with Moringa + No fertilizer

4.1.5 Number of Leaves Plant⁻¹

4.1.5.1 Effect of Production System

The present study aimed to investigate the variation in the number of leaves per Plant between two systems of a Plant species, with data collected at two different time points after sowing: 60 DAS and 70 DAS. The results, as summarized in (Table-4.13), at 60 DAS + 70 DAS, system S₂ (Lettuce with Moringa) exhibited the highest number of leaves per Plant, recording an average of 24.23 leaves. On the other hand, S₁ (Lettuce sole) exhibited the lowest number of leaves per Plant, recording an average of 17.90 leaves. These findings indicate that S₂ is more efficient in leaf production during the early stages of growth compared to the other system.

The importance of leaves in a Plant's growth and productivity is well-established. Leaves serve as the primary sites for photosynthesis, enabling Plants to synthesize food using sunlight, water, and carbon dioxide. The greater the number of leaves, the larger the surface area available for photosynthetic activity. Hence, a higher leaf count can positively influence the overall yield of a Plant.

Table-4.13: Effect of Production Systems on Number of Leaves Plant⁻¹

Treatments (Production Systems)	Number of Leaves Plant ⁻¹
	60 DAS + 70 DAS
S ₁	17.90 b
S ₂	24.23 a
CV%	8.72%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter (s) differ significantly.

Note: S₁ (Lettuce sole), S₂ (Lettuce with Moringa)

4.1.5.2 Fertilizer effect

The results of the study indicated at (Table-4.14) showed that there were significant differences in the number of leaves per Plant at different fertilizer applications under the different agroforestry production system. However, there were some variations observed in the number of leaves per Plant at different stages of the Plant's growth (60 DAS and

70 DAS). At 60 DAS +70 DAS, the highest number of leaves per Plant (23.70) was recorded in the treatment where chemical fertilizer (F₁) was applied, while the lowest number of leaves per Plant (19.07) was observed in the treatment where no fertilizer (F₄) was applied. So, it is said that the highest number of leaves per Plant was recorded in the treatment with chemical fertilizer (F₁), whereas the lowest number of leaves per Plant was observed in the treatment with no fertilizer (F₄).

Table-4.14: Effect of Fertilizer Applications on Number of Leaves Plant⁻¹

Treatments (Fertilizers)	Number of Leaves Plant ⁻¹
	60 DAS + 70 DAS
F ₁	23.70 a
F ₂	20.35 b
F ₃	21.10 ab
F ₄	19.07 b
CV (%)	8.72%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Note: F₁ (Chemical fertilizer), F₂ (Cow dung), F₃ (Poultry manure) and F₄ (No fertilizer).

4.1.5.3 Interaction Effect

The variations of number of leaves Plant⁻¹ due to the interaction effect of production systems and fertilizer applications were found significant in all the growth stages (Table-4.15). At 60 DAS + 70 DAS, the treatment S₂F₃, which involved using the system "Lettuce with Moringa" along with poultry manure, exhibited the highest number of leaves per Plant (25.57). On the other hand, the treatment S₁F₃, which used the system "Lettuce sole" with poultry manure, showed the lowest number of leaves per Plant (16.63).

These findings indicate that different production systems of lettuce Plants respond differently to various fertilizer treatments, and the combination of a specific system with the appropriate type of fertilizer can influence leaf production significantly.

Table-4.15: Interaction Effect of Production Systems and Fertilizer Applications on Number of Leaves Plant⁻¹

Production Systems × Fertilizer applications	Effect of Number of Leaves Plant ⁻¹
	60 DAS + 70 DAS
S ₁ F ₁	20.33 cd
S ₁ F ₂	17.48 d
S ₁ F ₃	16.63 d
S ₁ F ₄	17.17 d
S ₂ F ₁	27.07 a
S ₂ F ₂	23.23 abc
S ₂ F ₃	25.57 ab
S ₂ F ₄	20.97 bcd
CV (%)	8.72%

In a column, figures having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where, S₁F₁=(Lettuce sole + Chemical fertilizer),S₁F₂=(Lettuce sole + Cow dung),S₁F₃=(Lettuce sole + Poultry manure),S₁F₄ =(Lettuce sole + No fertilizer),S₂F₁ =(Lettuce with Moringa + Chemical fertilizer),S₂F₂ =(Lettuce with Moringa + Cow dung),S₂F₃ =(Lettuce with Moringa + Poultry manure), S₂F₄=(Lettuce with Moringa + No fertilizer).

4.1.6 Number of Leaves Plot⁻¹

4.1.6.1 Effect of Production Systems

The present study aimed to investigate the variation in the number of leaves per plot between two systems of a Plant species, with data collected at two different time points after sowing: 60 DAS and 70 DAS. The results, as summarized in (Table-4.16), at 60 DAS + 70 DAS, system S₂ (Lettuce with Moringa) exhibited the highest number of leaves (1452.5) per plot. On the other hand, S₁ (Lettuce sole) exhibited the lowest number of leaves (1074) per plot. These findings indicate that S₂ is more efficient in leaf production during the early stages of growth compared to the other system.

Table-4.16: Effect of Production Systems on Number of Leaves Plot⁻¹

Treatments (Production Systems)	Number of Leaves Plot ⁻¹
	60 DAS + 70 DAS
S ₁	1074.0 b
S ₂	1452.5 a
CV%	8.72%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter (s) differ significantly.

Note: S₁ (Lettuce sole), S₂ (Lettuce with Moringa)

4.1.6.2. Fertilizer effect

The results of the study indicated at (Table-4.17) showed that there were significant differences in the number of leaves per plot at different fertilizer applications under the moringa-based agroforestry system. However, there were some variations observed in the number of leaves per plot at different stages of the Plant's growth (60 DAS and 70 DAS). At 60 DAS + 70 DAS, the highest number of leaves per plot (1422) was recorded in the treatment where chemical fertilizer (F₁) was applied, while the lowest number of leaves per plot (1144) was observed in the treatment where no fertilizer (F₄) was applied.

The results suggest that, overall, the application of chemical fertilizer led to higher Plant growth in terms of the number of leaves per plot compared to no fertilizer treatments.

Table-4.17: Effect of Fertilizer Applications on Number of Leaves Plot⁻¹

Treatments (Fertilizers)	Number of Leaves Plot ⁻¹
	60 DAS + 70 DAS
F ₁	1422 a
F ₂	1221 b
F ₃	1266 ab
F ₄	1144 b
CV (%)	8.72%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Note: F₁ (Chemical fertilizer), F₂ (Cow dung), F₃ (Poultry manure) and F₄ (No fertilizer).

4.1.6.3 Interaction Effect

The variations of number of leaves Plot⁻¹ due to the interaction effect of production systems and fertilizer applications were found significant in all the growth stages (Table-4.18). At 60 DAS + 70 DAS, the treatment S₂F₁, which involved using the system "Lettuce with Moringa" along with chemical fertilizer, exhibited the highest number of leaves per plot (1624). On the other hand, the treatment S₁F₃, which used the system "Lettuce sole" with poultry manuring, showed the lowest number of leaves per Plant (998).

These findings indicate that different systems of lettuce plots respond differently to various fertilizer treatments, and the combination of a specific production system with the appropriate type of fertilizer can influence leaf production significantly.

Table-4.18: Interaction Effect of Production Systems and Fertilizer Applications on Number of Leaves Plot⁻¹

Production Systems × Fertilizer applications	Effect of Number of Leaves Plot ⁻¹
	60 DAS + 70 DAS
S ₁ F ₁	1220 cd
S ₁ F ₂	1048 d
S ₁ F ₃	998 d
S ₁ F ₄	1030 d
S ₂ F ₁	1624 a
S ₂ F ₂	1394 abc
S ₂ F ₃	1534 ab
S ₂ F ₄	1258 bcd
CV (%)	8.72%

In a column, figures having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where, S₁F₁=(Lettuce sole + Chemical fertilizer),S₁F₂=(Lettuce sole + Cow dung),S₁F₃=(Lettuce sole + Poultry manure),S₁F₄=(Lettuce sole + No fertilizer),S₂F₁=(Lettuce with Moringa + Chemical fertilizer),S₂F₂=(Lettuce with Moringa + Cow dung),S₂F₃=(Lettuce with Moringa + Poultry manure), S₂F₄=(Lettuce with Moringa + No fertilizer).

4.1.7 Leaves weight Plant⁻¹ (g)

4.1.7.1 Effect of Production Systems

The present study aimed to investigate the variation in the weight of leaves per Plant (g) between two systems of a Plant species, with data collected at two different time points after sowing i.e. 60 DAS and 70 DAS. The results, as summarized in (Table-4.19), demonstrated significant differences in the weight of leaves per Plant across the systems at all two time points. At the time of 60 DAS + 70 DAS, system S₂ (Lettuce with Moringa) exhibited the highest weight of leaves per Plant, recording an average of 203.91(g). On the other hand, S₁ (Lettuce sole) exhibited the lowest weight of leaves per Plant, recording an average of 108.83(g). These findings indicate that S₂ is more efficient in leaves production during the early stages of growth compared to the other system.

Table-4.19: Effect of Production Systems on Leaves weight Plant⁻¹ (g)

Treatments (Production Systems)	Leaves weight Plant⁻¹ (g)
	60 DAS + 70 DAS
S ₁	108.83 b
S ₂	203.91 a
CV%	21.28%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter (s) differ significantly.

Note: S₁ (Lettuce sole), S₂ (Lettuce with Moringa)

4.1.7.2 Fertilizer effect

The results of the study indicated at (Table-4.20) showed that there were significant differences in the weight of leaves per Plant at different fertilizer applications under the different agroforestry production systems. However, there were some variations observed in the weight of leaves per Plant at different stages of the Plant's growth (60 DAS and 70 DAS). At 60 DAS + 70 DAS, the highest weight of leaves per Plant (225.06 gm) was recorded in the treatment where chemical fertilizer (F₁) was applied, while the lowest weight of leaves per Plant (105.18 gm) was observed in the treatment where no fertilizer (F₄) was applied. So, It id said that the highest weight of leaves per Plant was

recorded in the treatment with chemical fertilizer (F₁), whereas the lowest weight of leaves per Plant was observed in the treatment with no fertilizer (F₄).

Table-4.20: Effect of Fertilizer Applications on Leaves weight Plant⁻¹ (g)

Treatments (Fertilizers)	Effect of Leaves weight Plant ⁻¹ (g)
	60 DAS + 70 DAS
F ₁	225.06 a
F ₂	138.97 b
F ₃	156.25 b
F ₄	105.18 b
CV (%)	21.28%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Note: F₁ (Chemical fertilizer), F₂ (Cow dung), F₃ (Poultry manure) and F₄ (No fertilizer).

4.1.7.3 Interaction Effect

The variations of weight of leaves Plant⁻¹ (g) due to the interaction effect of production systems and fertilizer applications were found significant in all the growth stages (Table-4.21). At 60 DAS + 70 DAS, the treatment S₂F₁, which involved using the production systems "Lettuce with Moringa" along with chemical fertilizer, exhibited the highest weight of leaves per Plant (285.76 gm). On the other hand, the treatment S₁F₄, which used the production system "Lettuce sole" with no fertilizer, showed the lowest weight of leaves per Plant (75.37 gm).

These findings indicate that different systems of lettuce plots respond differently to various fertilizer treatments, and the combination of a specific system with the appropriate type of fertilizer can influence leaf production significantly.

Table-4.21: Interaction Effect of Production Systems and Fertilizer Applications on Leaves weight Plant⁻¹ (g)

Production Systems × Fertilizer applications	Effect of Leaves weight Plant ⁻¹ (g)
	60 DAS + 70 DAS
S ₁ F ₁	164.37 bc
S ₁ F ₂	109.43 c
S ₁ F ₃	86.13 c
S ₁ F ₄	75.37 c
S ₂ F ₁	285.76 a
S ₂ F ₂	168.50 bc
S ₂ F ₃	226.37 ab
S ₂ F ₄	135 bc
CV (%)	21.28%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where, S₁F₁=(Lettuce sole + Chemical fertilizer),S₁F₂=(Lettuce sole + Cow dung),S₁F₃=(Lettuce sole + Poultry manure),S₁F₄ =(Lettuce sole + No fertilizer),S₂F₁ =(Lettuce with Moringa + Chemical fertilizer),S₂F₂ =(Lettuce with Moringa + Cow dung),S₂F₃ =(Lettuce with Moringa + Poultry manure), S₂F₄=(Lettuce with Moringa + No fertilizer).

4.1.8 Leaves Weight Plot⁻¹ (g)

4.1.8.1 Effect of Production Systems

The present study aimed to investigate the variation in the weight of leaves per plot (g) between two production systems of a Plant species, with data collected at two different time points after sowing i.e. 60 DAS and 70 DAS. The results, as summarized in (Table-4.22), demonstrated significant differences in the weight of leaves per plot across the systems at all two time points. At the time of 60 DAS + 70 DAS, system S₂ (Lettuce with Moringa) exhibited the highest weight of leaves per plot, recording an average of (12234 gm). On the other hand, S₁ (Lettuce sole) exhibited the lowest weight of leaves per plot, recording an average of (6030 gm). These findings indicate that S₂ is more efficient in leaf production during the early stages of growth compared to the other system.

Table-4.22: Effect of Production Systems on Leaves weight Plot⁻¹ (g)

Treatments (Production Systems)	Leaves weight Plot ⁻¹ (g)
	60 DAS + 70 DAS
S ₁	6030 b
S ₂	12234 a
CV%	17.52

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter (s) differ significantly.

Note: S₁ (Lettuce sole), S₂ (Lettuce with Moringa)

4.1.8.2 Fertilizer effect

The results of the study indicated at (Table-4.23) showed that there were significant differences in the weight of leaves per plot at different fertilizer applications under the different agroforestry production systems. There were some variations observed in the weight of leaves per plot at different stages of the Plant's growth (60 DAS and 70 DAS). At 60 DAS + 70 DAS, the highest weight of leaves per plot (13504 gm) was recorded in the treatment where chemical fertilizer (F₁) was applied, while the lowest weight of leaves per plot (6311 gm) was observed in the treatment where no fertilizer (F₄) was applied. So, It id said that the highest weight of leaves per plot was recorded in the treatment with chemical fertilizer (F₁), whereas the lowest weight of leaves per plot was observed in the treatment with no fertilizer (F₄).

Table-4.23: Effect of Fertilizer Applications on Leaves weight Plot⁻¹ (g)

Treatments (Fertilizers)	Effect of Leaves weight Plot ⁻¹ (g)
	60 DAS + 70 DAS
F ₁	13504 a
F ₂	7338 bc
F ₃	9375 b
F ₄	6311 c
CV (%)	17.52

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Note: F₁ (Chemical fertilizer), F₂ (Cow dung), F₃ (Poultry manure) and F₄ (No fertilizer).

Table-4.24: Interaction Effect of Production Systems and Fertilizer Applications on Leaves weight Plot⁻¹ (g)

Production Systems × Fertilizer applications	Effect of Leaves weight Plot ⁻¹ (g)
	60 DAS + 70 DAS
S ₁ F ₁	9862 bc
S ₁ F ₂	4566 d
S ₁ F ₃	5168 d
S ₁ F ₄	4522 d
S ₂ F ₁	17146 a
S ₂ F ₂	10110 bc
S ₂ F ₃	13582 ab
S ₂ F ₄	8100 cd
CV (%)	17.52

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where, S₁F₁=(Lettuce sole + Chemical fertilizer),S₁F₂=(Lettuce sole + Cow dung),S₁F₃=(Lettuce sole + Poultry manure),S₁F₄ =(Lettuce sole + No fertilizer),S₂F₁ =(Lettuce with Moringa + Chemical fertilizer),S₂F₂ = (Lettuce with Moringa + Cow dung),S₂F₃ =(Lettuce with Moringa + Poultry manure), S₂F₄=(Lettuce with Moringa + No fertilizer.)

4.2 Plant Yield Characters

4.2.1 Yield of Lettuce Plant⁻¹ (kg)

4.2.1.1 Effect of Production Systems

The study aimed to investigate the effect of production systems on yield of lettuce Plant⁻¹ (kg). The analysis of the experimental data revealed that there was a significant difference in yield of lettuce Plant⁻¹ between the different lettuce production systems. The maximum yield of lettuce per Plant (0.203 kg) was observed in S₂ (Lettuce + Moringa) system. This indicates that (Lettuce + Moringa) had the highest potential to produce larger leaves compared to the other systems under the study. On the other hand, the minimum yield of lettuce per Plant (0.101kg) was recorded in S₁ (Lettuce sole)

system. This suggests that (lettuce sole) had the lowest yield of lettuce compared to the other system.

The results, as summarized in (Table-4.25), demonstrated significant differences in the yield of lettuce per Plant across the production systems at all two time points. At the time of 60 DAS and 70 DAS.

Table-4.25: Effect of Production Systems on Yield of lettuce Plant⁻¹ (kg)

Treatments (Production Systems)	Yield of lettuce Plant ⁻¹ (kg)
	60 DAS + 70 DAS
S ₁	0.1008 b
S ₂	0.2025 a
CV%	17.34

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter (s) differ significantly.

Note: S₁ (Lettuce sole), S₂ (Lettuce with Moringa)

4.2.1.2 Fertilizer effect

The study aimed to investigate the impact of different fertilizer applications on yield of lettuce per Plant under different production systems (Table-4.26). The results indicated that the fertilizer applications had a significant effect on yield of lettuce, leading to variations in lettuce Plant weight and development. Among the different fertilizer treatments, F₁ (Chemical fertilizer) application resulted in the highest yield of lettuce per Plant, recording 0.23 kg. On the other hand, the F₄ treatment (No fertilizer) showed the lowest yield of lettuce, measuring 0.11 kg.

This result indicates that without the addition of fertilizers, the lettuce Plants had limited access to essential nutrients, leading to reduced growth and smaller leaf formation.

Table-4.26: Effect of Fertilizer Applications on Yield of lettuce Plant⁻¹ (kg)

Treatments (Fertilizers)	Yield of lettuce Plant ⁻¹ (kg)
	60 DAS + 70 DAS
F ₁	0.2250 a
F ₂	0.1200 bc
F ₃	0.1567 b
F ₄	0.1050 c
CV (%)	17.34

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Note: F₁ (Chemical fertilizer), F₂ (Cow dung), F₃ (Poultry manure) and F₄ (No fertilizer).

4.2.1.3 Interaction Effect

The study investigated the impact of different treatment combinations on yield of lettuce Plant⁻¹ (kg). The results revealed that there was a statistically significant interaction effect between production systems and fertilizer applications, as shown in Table-(4.27). Among the various treatment combinations, the maximum yield of lettuce recorded was (0.29 kg) per Plant, and it was observed in the treatment S₂F₁, which consisted of the production systems "Lettuce + Moringa" combined with chemical fertilizer. On the other hand, the minimum yield of lettuce (0.073 kg) per Plant was found in the treatment S₁F₂, involving the system "Lettuce sole" with cow dung application.

Table-4.27: Interaction Effect of Production Systems and Fertilizer Applications on Yield of lettuce Plant⁻¹ (kg)

Production Systems × Fertilizer Applications	Yield of lettuce Plant⁻¹ (kg)
S ₁ F ₁	0.1633 bcd
S ₁ F ₂	0.0733 e
S ₁ F ₃	0.0900 de
S ₁ F ₄	0.0767 e
S ₂ F ₁	0.2867 a
S ₂ F ₂	0.1667 dc
S ₂ F ₃	0.2233 ab
S ₂ F ₄	0.1333 cde
CV (%)	17.34

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where, S₁F₁=(Lettuce sole + Chemical fertilizer),S₁F₂=(Lettuce sole + Cow dung),S₁F₃=(Lettuce sole + Poultry manure),S₁F₄=(Lettuce sole + No fertilizer),S₂F₁=(Lettuce with Moringa + Chemical fertilizer),S₂F₂=(Lettuce with Moringa + Cow dung),S₂F₃=(Lettuce with Moringa + Poultry manure), S₂F₄=(Lettuce with Moringa + No fertilizer.)

4.2.2 Yield of lettuce Plot⁻¹ (kg)

4.2.2.1 Effect of Production Systems

The study aimed to investigate the effect of production systems on yield of lettuce per plot (kg). The analysis of the experimental data revealed that there was a significant difference in the yield of lettuce per plot between the different lettuce production systems (Table-4.28). The maximum yield of lettuce per plot (12.23 kg) was observed in S₂ (Lettuce + Moringa) system. This indicates that (Lettuce + Moringa) had the highest potential to produce larger and healthy leaves compared to the other production systems under the study. On the other hand, the minimum yield of lettuce per plot (6.03 kg) was recorded in S₁ (Lettuce sole) production system. This suggests that (lettuce sole) had the lowest and smaller leaves compared to the other production system.

Table-4.28: Effect of Production Systems on Yield of lettuce Plot⁻¹ (kg)

Treatments (Production Systems)	Yield of lettuce Plot ⁻¹ (kg)
	60 DAS + 70 DAS
S ₁	6.03 b
S ₂	12.23 a
CV%	17.53%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter (s) differ significantly.

Note: S₁ (Lettuce sole), S₂ (Lettuce with Moringa)

4.2.2.2 Fertilizer Effect

The study aimed to investigate the impact of different fertilizer applications on yield of lettuce per plot under different agroforestry production systems (Table-4.29). The results indicated that the fertilizer applications had a significant effect on yield of lettuce per plot, leading to variations in lettuce Plant growth and development. Among the different fertilizer treatments, F₁ (Chemical fertilizer) application resulted in the highest yield of lettuce per plot, recording (13.50 kg). On the other hand, the F₄ treatment (No fertilizer) showed the lowest yield of lettuce per plot measuring (6.31) kg.

4.2.2.3 Interaction Effect

The study investigated the impact of different treatment combinations on yield of lettuce Plot⁻¹ (kg). The results revealed that there was a statistically significant interaction effect between production systems and fertilizer applications, as shown in Table-(4.30). Among the various treatment combinations, the maximum yield of lettuce recorded was (17.14 kg), and it was observed in the treatment S₂F₁, which consisted of the production system "Lettuce + Moringa" combined with chemical fertilizer. On the other hand, the minimum yield of lettuce (4.52 kg) was found in the treatment S₁F₄, involving the production system "Lettuce sole" without any fertilizer application.

Table-4.29: Effect of Fertilizer Applications on Yield of lettuce Plot⁻¹ (kg)

Treatments (Fertilizers)	Yield of lettuce Plot ⁻¹ (kg)
	60 DAS + 70 DAS
F ₁	13.50 a
F ₂	7.34 bc
F ₃	9.38 b
F ₄	6.31 c
CV (%)	17.53

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Note: F₁ (Chemical fertilizer), F₂ (Cow dung), F₃ (Poultry manure) and F₄ (No fertilizer).

Table-4.30: Interaction Effect of Production Systems and Fertilizer Applications on Yield of lettuce Plot⁻¹ (kg)

Production Systems × Fertilizer Applications	Yield of lettuce Plot ⁻¹ (kg)
S ₁ F ₁	9.86 bc
S ₁ F ₂	4.57 d
S ₁ F ₃	5.17 d
S ₁ F ₄	4.52 d
S ₂ F ₁	17.14 a
S ₂ F ₂	10.11 bc
S ₂ F ₃	13.58 ab
S ₂ F ₄	8.10 cd
CV (%)	17.53

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where, S₁F₁=(Lettuce sole + Chemical fertilizer),S₁F₂=(Lettuce sole + Cow dung),S₁F₃=(Lettuce sole + Poultry manure),S₁F₄ =(Lettuce sole + No fertilizer),S₂F₁ =(Lettuce with Moringa + Chemical fertilizer),S₂F₂ = (Lettuce with Moringa + Cow dung),S₂F₃=(Lettuce with Moringa + Poultry manure), S₂F₄=(Lettuce with Moringa + No fertilizer.)

4.2.3 Yield of lettuce (t ha⁻¹)

4.2.3.1 Effect of Production Systems

The study aimed to investigate the effect of production systems on yield of lettuce (t ha⁻¹). The analysis of the experimental data revealed that there was a significant difference in yield of lettuce (t ha⁻¹) between the different lettuce production systems (Table-4.31). The maximum yield of lettuce 20.39 (t ha⁻¹) was observed in S₂ (Lettuce + Moringa) production system. This indicates that (Lettuce + Moringa) had the highest potential to produce larger and healthier leaves compared to the other production systems under the study. On the other hand, the minimum yield of lettuce 10.05 (t ha⁻¹) was recorded in S₁ (Lettuce sole) production system. This suggests that (lettuce sole) had the lowest and smaller leaves weight compared to the other production system.

Table-4.31: Effect of Production Systems on Yield of lettuce (t ha⁻¹)

Treatments (Production Systems)	Yield of lettuce (t ha ⁻¹)
	60 DAS + 70 DAS
S ₁	10.05 b
S ₂	20.39 a
CV%	17.53%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter (s) differ significantly.

Note: S₁ (Lettuce sole), S₂ (Lettuce with Moringa)

4.2.3.2 Fertilizer effect

The study aimed to investigate the impact of different fertilizer applications on Yield of lettuce (t ha⁻¹) under different agroforestry production systems (Table-4.32). The results indicated that the fertilizer applications had a significant effect on yield of lettuce, leading to variations in lettuce Plant growth and development. Among the different fertilizer treatments, F₁ (Chemical fertilizer) application resulted in the highest yield of lettuce, recording 22.51 (t ha⁻¹). On the other hand, the F₄ treatment (No fertilizer) showed the lowest yield of lettuce, measuring 10.52 (t ha⁻¹).

This result indicates that without the addition of fertilizers, the lettuce Plants had limited access to essential nutrients, leading to reduced growth and smaller leaf formation.

Table-4.32: Effect of Fertilizer Applications on Yield of lettuce (t ha⁻¹)

Treatments (Fertilizers)	Yield of lettuce (t ha ⁻¹)
	60 DAS + 70 DAS
F ₁	22.51 a
F ₂	12.23 bc
F ₃	15.63 b
F ₄	10.52 c
CV (%)	17.53

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Note: F₁ (Chemical fertilizer), F₂ (Cow dung), F₃ (Poultry manure) and F₄ (No fertilizer).

4.2.3.3 Interaction Effect

The study investigated the impact of different treatment combinations on yield of lettuce (t ha⁻¹). The results revealed that there was a statistically significant interaction effect between production systems and fertilizer applications, as shown in Table-(4.33). Among the various treatment combinations, the maximum yield of lettuce recorded was 28.57 (t ha⁻¹), and it was observed in the treatment S₂F₁, which consisted of the production system "Lettuce + Moringa" combined with chemical fertilizer. On the other hand, the minimum yield of lettuce 7.53 (t ha⁻¹) was found in the treatment S₁F₄, involving the system "Lettuce sole" without any fertilizer application.

Table-4.33: Interaction Effect of Production Systems and Fertilizer Applications on Yield of lettuce (t ha⁻¹)

Production Systems × Fertilizer Applications	Yield of lettuce (t ha⁻¹)
S ₁ F ₁	16.44 bc
S ₁ F ₂	7.61 d
S ₁ F ₃	8.61 d
S ₁ F ₄	7.53 d
S ₂ F ₁	28.57 a
S ₂ F ₂	16.85 bc
S ₂ F ₃	22.64 ab
S ₂ F ₄	13.50 cd
CV (%)	17.53

In a column, figures having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where, S₁F₁=(Lettuce sole + Chemical fertilizer),S₁F₂=(Lettuce sole + Cow dung),S₁F₃=(Lettuce sole + Poultry manure),S₁F₄=(Lettuce sole + No fertilizer),S₂F₁=(Lettuce with Moringa + Chemical fertilizer),S₂F₂=(Lettuce with Moringa + Cow dung),S₂F₃=(Lettuce with Moringa + Poultry manure), S₂F₄=(Lettuce with Moringa + No fertilizer.)

4.2.4 Dry weight (g)

4.2.4.1 Effect of Production Systems

The study aimed to investigate the effect of production systems on dry weight in (g). The analysis of the experimental data revealed that there was a significant difference in dry weight between the different lettuce production systems (Table-4.34). The maximum dry weight of lettuce 10.67 gm. was observed in S₁ (Lettuce sole) production system. This indicates that (Lettuce sole) had the highest potential of dry weight compared to the other production systems under the study. On the other hand, the minimum dry weight of lettuce 9.31 gm was recorded in S₂ (Lettuce + Moringa) production system. This suggests that (Lettuce + Moringa) had the lowest dry weight compared to the other production system.

Table-4.34: Effect of Production Systems on Dry weight (g)

Treatments (Production Systems)	Dry weight (g)
	60 DAS + 70 DAS
S ₁	10.67 a
S ₂	9.31 b
CV (%)	10.80

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter (s) differ significantly.

Note: S₁ (Lettuce sole), S₂ (Lettuce with Moringa)

4.2.4.2 Fertilizer Effect

The study aimed to investigate the impact of different fertilizer applications on dry weight of lettuce (g) under different agroforestry production systems (Table-4.35). The results indicated that the fertilizer applications had a significant effect on dry weight, leading to variations in lettuce Plant growth and development. Among the different fertilizer treatments, F₄ (No fertilizer) application resulted in the highest dry weight of lettuce, recording 10.84 (g). On the other hand, the F₃ treatment (Poultry manure) showed the lowest yield of lettuce, measuring 9.30 (g).

This result indicates that with the addition of poultry manuring, the lettuce Plants had limited access to essential nutrients, leading to reduced growth and smaller leaf formation.

Table-4.35: Effect of Fertilizer Applications on Dry weight (g)

Treatments (Fertilizers)	Dry weight (g)
	60 DAS + 70 DAS
F ₁	9.71 a
F ₂	10.12 a
F ₃	9.30 a
F ₄	10.84 a
CV (%)	10.80%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Note: F₁ (Chemical fertilizer), F₂ (Cow dung), F₃ (Poultry manure) and F₄ (No fertilizer).

4.2.4.3 Interaction Effect

The study investigated the impact of different treatment combinations on dry weight of lettuce (g). The results revealed that there was a statistically significant interaction effect between production systems and fertilizer applications, as shown in Table-(4.36). Among the various treatment combinations, the maximum dry weight of lettuce recorded was 11.36 (g), and it was observed in the treatment S_1F_4 , which consisted of the production system "Lettuce sole" combined with no fertilizer. On the other hand, the minimum yield of lettuce 8.92 (g) were found in the treatment S_2F_1 and S_2F_2 , involving the system "Lettuce + Moringa" with chemical fertilizer cow dung applications.

Table-4.36: Interaction Effect of Production Systems and Fertilizer Applications on Dry weight (g)

Production Systems × Fertilizer Applications	Dry weight (g)
S_1F_1	10.50 a
S_1F_2	11.32 a
S_1F_3	9.51 a
S_1F_4	11.36 a
S_2F_1	8.92 a
S_2F_2	8.92 a
S_2F_3	9.09 a
S_2F_4	10.32 a
CV (%)	4.26

In a column, figures having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where, S_1F_1 = (Lettuce sole + Chemical fertilizer), S_1F_2 = (Lettuce sole + Cow dung), S_1F_3 = (Lettuce sole + Poultry manure), S_1F_4 = (Lettuce sole + No fertilizer), S_2F_1 = (Lettuce with Moringa + Chemical fertilizer), S_2F_2 = (Lettuce with Moringa + Cow dung), S_2F_3 = (Lettuce with Moringa + Poultry manure), S_2F_4 = (Lettuce with Moringa + No fertilizer.)

4.3 Quality Characters

4.3.1 Moisture (%)

4.3.1.1 Effect of Production Systems

The results of the study, as depicted in (Table-4.37), showed that there were significant differences between the production systems in terms of their moisture percentages. The maximum moisture percentage (87.94 %) was observed in S₂ (Lettuce + Moringa) production system. On the other hand, the minimum moisture percentage (86.13 %) was found in S₁ (Lettuce sole) production system.

Table-4.37: Effect of Production Systems on Moisture (%)

Treatments (Production Systems)	Moisture (%)
S ₁	86.13 a
S ₂	87.94 a
CV (%)	4.26

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter (s) differ significantly.

Note: S₁ (Lettuce sole), S₂ (Lettuce with Moringa)

4.3.1.2 Fertilizer Effect

The moisture content of lettuce was influenced by different fertilizer applications in the different agroforestry production systems (Table-4.38) presents the moisture percentages obtained from various treatments. Among the treatments, the highest moisture percentage of 87.63 % was recorded in Treatment F₁, where Chemical fertilizer was applied. Conversely, Treatment F₂, which received cow dung application, showed the lowest moisture percentage of 86.32%. These findings indicate that the choice of fertilizer application significantly impacts the moisture content of lettuce.

Table-4.38: Effect of Fertilizer Applications on Moisture (%)

Treatments (Fertilizers)	Moisture (%)
F ₁	87.63 a
F ₂	86.32 a
F ₃	87.10 a
F ₄	87.08 a
CV (%)	4.26%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Note: F₁ (Chemical fertilizer), F₂ (Cow dung), F₃ (Poultry manure) and F₄ (No fertilizer).

4.3.1.3 Interaction Effect

The study investigated the impact of different production systems and fertilizer applications in different agroforestry production system on the moisture percentage of lettuce. The data presented in (Table-4.39) showed significant variations in lettuce moisture % due to the interaction between production systems and fertilizer applications. Among the different treatment combinations, the highest moisture % of lettuce (89.95 %) was observed in the treatment S_2F_1 , which involved the production system "Lettuce + Moringa" combined with chemical fertilizer. On the other hand, the lowest moisture % of lettuce (85.31 %) was recorded in the treatment S_1F_1 , which included the production system "Lettuce sole" with chemical fertilizer applications.

Table-4.39: Interaction Effect of Production Systems and Fertilizer Applications on Moisture (%)

Production Systems × Fertilizer Applications	Moisture (%)
S_1F_1	85.31 a
S_1F_2	86.04 a
S_1F_3	86.46 a
S_1F_4	86.70 a
S_2F_1	89.95 a
S_2F_2	86.59 a
S_2F_3	87.73 a
S_2F_4	87.47 a
CV%	4.26%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where, S_1F_1 =(Lettuce sole + Chemical fertilizer), S_1F_2 =(Lettuce sole + Cow dung), S_1F_3 =(Lettuce sole + Poultry manure), S_1F_4 =(Lettuce sole + No fertilizer), S_2F_1 =(Lettuce with Moringa + Chemical fertilizer), S_2F_2 =(Lettuce with Moringa + Cow dung), S_2F_3 =(Lettuce with Moringa + Poultry manure), S_2F_4 =(Lettuce with Moringa + No fertilizer.)

4.3.2 Dry matter (%)

4.3.2.1 Effect of Production Systems

The results of the study, as depicted in (Table-4.40), showed that there were significant differences between the production systems in terms of their dry matter percentages. The maximum dry matter percentage (14.04 %) was observed in S₁ (Lettuce sole) production system. On the other hand, the minimum moisture percentage (11.82 %) was found in S₂ (Lettuce + Moringa) system.

Table-4.40: Effect of Production Systems on Dry matter (%)

Treatments (Production Systems)	Dry matter (%)
S ₁	14.04 a
S ₂	11.82 b
CV%	7.86%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter (s) differ significantly.

Note: S₁ (Lettuce sole), S₂ (Lettuce with Moringa)

4.3.2.2 Fertilizer Effect

The dry matter content of lettuce was influenced by different fertilizer applications in the different agroforestry production system (Table-4.41) presents the dry matter percentages obtained from various treatments. Among the treatments, the highest moisture percentage of 13.69 % was recorded in Treatment F₂, where cow dung was applied. Conversely, Treatment F₁, which received chemical fertilizer application, showed the lowest dry matter percentage of 11.87 %. These findings indicate that the choice of fertilizer application significantly impacts the dry matter of lettuce.

Table-4.41: Effect of Fertilizer Applications on Dry matter (%)

Treatments (Fertilizers)	Dry matter (%)
F ₁	11.87 b
F ₂	13.69 a
F ₃	12.91 ab
F ₄	13.25 ab
CV (%)	7.86%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Note: F₁ (Chemical fertilizer), F₂ (Cow dung), F₃ (Poultry manure) and F₄ (No fertilizer).

4.3.2.3 Interaction Effect

The study investigated the impact of different production systems and fertilizer applications in different agroforestry production systems on the dry matter percentage of lettuce. The data presented in (Table-4.42) showed significant variations in lettuce dry matter % due to the interaction between production systems and fertilizer applications. Among the different treatment combinations, the highest dry matter % of lettuce (14.69 %) was observed in the treatment S_1F_1 , which involved the production system "Lettuce sole" combined with chemical fertilizer. On the other hand, the lowest dry matter % of lettuce (9.05 %) was recorded in the treatment S_2F_1 , which included the production systems "Lettuce + Moringa" with chemical fertilizer application.

Table-4.42: Interaction Effect of Production Systems and Fertilizer Applications on Dry matter (%)

Production Systems × Fertilizer Applications	Dry matter (%)
S_1F_1	14.69 a
S_1F_2	13.96 a
S_1F_3	13.54 a
S_1F_4	13.97 a
S_2F_1	9.05 b
S_2F_2	13.41 a
S_2F_3	12.27 a
S_2F_4	12.53 a
CV (%)	7.86

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where, S_1F_1 =(Lettuce sole + Chemical fertilizer), S_1F_2 =(Lettuce sole + Cow dung), S_1F_3 =(Lettuce sole + Poultry manure), S_1F_4 =(Lettuce sole + No fertilizer), S_2F_1 =(Lettuce with Moringa + Chemical fertilizer), S_2F_2 =(Lettuce with Moringa + Cow dung), S_2F_3 =(Lettuce with Moringa + Poultry manure), S_2F_4 =(Lettuce with Moringa + No fertilizer.)

4.3.3 Protein (%)

4.3.3.1 Effect of Production Systems

The results of the study, as depicted in (Table-4.43), showed that there were significant differences between the production systems in terms of their protein %. The maximum protein (2.40 %) was observed in S₁ (“Lettuce sole”) production system. On the other hand, the minimum protein (2.17 %) was found in S₂ (Lettuce + Moringa) production system.

Table-4.43: Effect of Production Systems on Protein (%)

Treatments (Production Systems)	Protein (%)
S ₁	2.4000 a
S ₂	2.1675 a
CV%	26.46%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter (s) differ significantly.

Note: S₁ (Lettuce sole), S₂ (Lettuce with Moringa)

4.3.3.2 Fertilizer Effect

The Protein content of lettuce was influenced by different fertilizer applications in the different agroforestry production system (Table-4.44) presents the protein % obtained from various treatments. Among the treatments, the highest protein% of 2.42 % was recorded in Treatment F₁, where Chemical fertilizer was applied. Conversely, Treatment F₄, which received no fertilizer application, showed the lowest protein of 2.13 %. These findings indicate that the choice of fertilizer application significantly impacts the protein % of lettuce.

Table-4.44: Effect of Fertilizer Applications on Protein (%)

Treatments (Fertilizers)	Protein (%)
F ₁	2.4150 a
F ₂	2.2250 a
F ₃	2.3700 a
F ₄	2.1250 a
CV (%)	26.46%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Note: F₁ (Chemical fertilizer), F₂ (Cow dung), F₃ (Poultry manure) and F₄ (No fertilizer).

4.3.3.3 Interaction Effect

The study investigated the impact of different production systems and fertilizer applications in different agroforestry production systems on the protein % of lettuce. The data presented in (Table-4.45) showed significant variations in lettuce protein % due to the interaction between production systems and fertilizer applications. Among the different treatment combinations, the highest protein % of lettuce (3.02 %) was observed in the treatment S₂F₂, which involved the production system "Lettuce + Moringa" combined with cow dung. On the other hand, the lowest protein % of lettuce (1.42 %) was recorded in the treatment S₂F₄, which included the production system "Lettuce + Moringa" without any fertilizer application.

Table-4.45: Interaction Effect of Production Systems and Fertilizer Applications on Protein (%)

Production Systems × Fertilizer Applications	Protein (%)
S ₁ F ₁	2.6300 a
S ₁ F ₂	1.4300 a
S ₁ F ₃	2.7100 a
S ₁ F ₄	2.8300 a
S ₂ F ₁	2.2000 a
S ₂ F ₂	3.0200 a
S ₂ F ₃	2.0300 a
S ₂ F ₄	1.4200 a
CV(%)	26.46%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where, S₁F₁=(Lettuce sole + Chemical fertilizer),S₁F₂=(Lettuce sole + Cow dung),S₁F₃=(Lettuce sole + Poultry manure),S₁F₄ =(Lettuce sole + No fertilizer),S₂F₁ =(Lettuce with Moringa + Chemical fertilizer),S₂F₂ =(Lettuce with Moringa + Cow dung),S₂F₃ =(Lettuce with Moringa + Poultry manure), S₂F₄=(Lettuce with Moringa + No fertilizer.)

4.3.4 Ash (%)

4.3.4.1 Effect of Production Systems

The results of the study, as depicted in (Table-4.46), showed that there were significant differences between the production systems in terms of their ash %. The maximum ash (1.89 %) was observed in S₁ (Lettuce sole) production system. On the other hand, the minimum ash (1.38 %) was found in S₂ (Lettuce + Moringa) production system.

Table-4.46: Effect of Production Systems on Ash (%)

Treatments (Production Systems)	Ash (%)
S ₁	1.8850 a
S ₂	1.3775 b
CV%	7.78%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter (s) differ significantly.

Note: S₁ (Lettuce sole), S₂ (Lettuce with Moringa)

4.3.4.2 Fertilizer effect

The Ash content of lettuce was influenced by different fertilizer applications in different agroforestry production systems (Table-4.47) presents the ash % obtained from various treatments. Among the treatments, the highest ash % of 2.57 % was recorded in Treatment F₂, where cow dung was applied. Conversely, Treatment F₁, which received chemical fertilizer application, showed the lowest ash % of 1.01 %. These findings indicate that the choice of fertilizer applications significantly impacts the ash of lettuce.

Table-4.47: Effect of Fertilizer Applications on Ash (%)

Treatments (Fertilizers)	Ash (%)
F ₁	1.0050 c
F ₂	2.5650 a
F ₃	1.8150 b
F ₄	1.1400 c
CV (%)	26.46%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Note: F₁ (Chemical fertilizer), F₂ (Cow dung), F₃ (Poultry manure) and F₄ (No fertilizer).

4.3.4.3 Interaction Effect

The study investigated the impact of different production systems and fertilizer applications in different agroforestry production systems on the ash % of lettuce. The data presented in (Table-4.48) showed significant variations in lettuce ash % due to the interaction between production systems and fertilizer applications. Among the different treatment combinations, the highest ash % of lettuce (3.37 %) was observed in the treatment S_1F_2 , which involved the system "Lettuce sole" combined with cow dung. On the other hand, the lowest ash % of lettuce (0.91 %) was recorded in the treatment S_2F_1 , which included the system "Lettuce + Moringa" with chemical fertilizer applications.

Table-4.48: Interaction Effect of Production Systems and Fertilizer Applications on Ash (%)

Production Systems × Fertilizer Applications	Ash (%)
S_1F_1	1.1000 c
S_1F_2	3.3700 a
S_1F_3	1.8600 b
S_1F_4	1.2100 c
S_2F_1	0.9100 c
S_2F_2	1.7600 b
S_2F_3	1.7700 b
S_2F_4	1.0700 c
CV (%)	26.46

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where, S_1F_1 =(Lettuce sole + Chemical fertilizer), S_1F_2 =(Lettuce sole + Cow dung), S_1F_3 =(Lettuce sole + Poultry manure), S_1F_4 =(Lettuce sole + No fertilizer), S_2F_1 =(Lettuce with Moringa + Chemical fertilizer), S_2F_2 = (Lettuce with Moringa + Cow dung), S_2F_3 =(Lettuce with Moringa + Poultry manure), S_2F_4 =(Lettuce with Moringa + No fertilizer.)

4.3.5 Chlorophyll a (mg g⁻¹)

4.3.5.1 Effect of Production Systems

The results of the study, as depicted in (Table-4.49), showed that there were significant differences between the production systems in terms of their chlorophyll a (mg g⁻¹). The maximum chlorophyll a (5.223 mg g⁻¹) was observed in S₂ (Lettuce + Moringa) production system. On the other hand, the minimum chlorophyll a (5.10 mg g⁻¹) was found in S₁ (Lettuce sole) production system.

Table-4.49: Effect of Production Systems on Chlorophyll a (mg g⁻¹)

Treatments (Production Systems)	Chlorophyll a (mg g ⁻¹)
S ₁	5.1000 a
S ₂	5.2225 a
CV(%)	7.57%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter (s) differ significantly.

Note: S₁ (Lettuce sole), S₂ (Lettuce with Moringa)

4.3.5.2 Fertilizer effect

The chlorophyll a of lettuce was influenced by different fertilizer applications in different agroforestry production systems (Table-4.50) presents the chlorophyll a obtained from various treatments. Among the treatments, the highest chlorophyll a of 5.51 mg g⁻¹ was recorded in Treatment F₁, where Chemical fertilizer was applied. Conversely, Treatment F₂, which received cow dung application, showed the lowest chlorophyll a of 5.00 mg g⁻¹. These findings indicate that the choice of fertilizer application significantly impacts the chlorophyll a of lettuce.

Table-4.50: Effect of Fertilizer Applications on Chlorophyll a (mg g⁻¹)

Treatments (Fertilizers)	Chlorophyll a (mg g ⁻¹)
F ₁	5.5100 a
F ₂	5.0000 a
F ₃	5.0500 a
F ₄	5.0850 a
CV (%)	7.57

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Note: F₁ (Chemical fertilizer), F₂ (Cow dung), F₃ (Poultry manure) and F₄ (No fertilizer).

4.3.5.3 Interaction Effect

The study investigated the impact of different production systems and fertilizer applications in different agroforestry production systems on the chlorophyll a of lettuce. The data presented in (Table-4.51) showed significant variations in lettuce chlorophyll a due to the interaction between production systems and fertilizer applications. Among the different treatment combinations, the highest chlorophyll a of lettuce (5.76 mg g^{-1}) was observed in the treatment S_2F_1 , which involved the production system "Lettuce + Moringa" combined with chemical fertilizer. On the other hand, the lowest chlorophyll a of lettuce (4.48 mg g^{-1}) was recorded in the treatment S_1F_2 , which included the production systems "Lettuce sole" with cow dung application.

Table-4.51: Interaction Effect of Production Systems and Fertilizer Applications on Chlorophyll a (mg g^{-1})

Production Systems × Fertilizer Applications	Chlorophyll a (mg g^{-1})
S_1F_1	5.2600 ab
S_1F_2	4.4800 b
S_1F_3	5.5300 ab
S_1F_4	5.1300 ab
S_2F_1	5.7600 a
S_2F_2	5.5200 ab
S_2F_3	4.5700 b
S_2F_4	5.0400 ab
CV (%)	7.57

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where, S_1F_1 =(Lettuce sole + Chemical fertilizer), S_1F_2 =(Lettuce sole + Cow dung), S_1F_3 =(Lettuce sole + Poultry manure), S_1F_4 =(Lettuce sole + No fertilizer), S_2F_1 =(Lettuce with Moringa + Chemical fertilizer), S_2F_2 =(Lettuce with Moringa + Cow dung), S_2F_3 =(Lettuce with Moringa + Poultry manure), S_2F_4 =(Lettuce with Moringa + No fertilizer.)

4.3.6 Chlorophyll b (mg g⁻¹)

4.3.6.1 Effect of Production Systems

The results of the study, as depicted in (Table-4.52), showed that there were significant differences between the production systems in terms of their chlorophyll b (mg g⁻¹). The maximum chlorophyll b (2.22 mg g⁻¹) was observed in S₂ (Lettuce + Moringa) production system. On the other hand, the minimum chlorophyll b (1.94 mg g⁻¹) was found in S₁ (Lettuce sole) production system.

Table-4.52: Effect of Production Systems on Chlorophyll b (mg g⁻¹)

Treatments (Production Systems)	Chlorophyll b (mg g ⁻¹)
S ₁	1.9350 b
S ₂	2.2233 a
CV(%)	13.63

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter (s) differ significantly.

Note: S₁ (Lettuce sole), S₂ (Lettuce with Moringa)

4.3.6.2 Fertilizer Effect

The chlorophyll b of lettuce was influenced by different fertilizer applications in different agroforestry production system (Table-4.53) presents the chlorophyll b obtained from various treatments. Among the treatments, the highest chlorophyll b of 2.18 mg g⁻¹ was recorded in Treatment F₃, where poultry manure was applied. Conversely, Treatment F₄, which received no fertilizer application, showed the lowest chlorophyll b of 1.98 mg g⁻¹. These findings indicate that the choice of fertilizer application significantly impacts the chlorophyll b of lettuce.

Table-4.53: Effect of Fertilizer Applications on Chlorophyll b (mg g⁻¹)

Treatments (Fertilizers)	Chlorophyll b (mg g ⁻¹)
F ₁	2.1500 a
F ₂	2.0150 a
F ₃	2.1767 a
F ₄	1.9750 a
CV (%)	13.63

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Note: F₁ (Chemical fertilizer), F₂ (Cow dung), F₃ (Poultry manure) and F₄ (No fertilizer).

4.3.6.3 Interaction Effect

The study investigated the impact of different production systems and fertilizer applications in different agroforestry production system on the chlorophyll b (mg g^{-1}) of lettuce. The data presented in (Table-4.54) showed significant variations in lettuce chlorophyll b due to the interaction between production systems and fertilizer applications. Among the different treatment combinations, the highest chlorophyll b of lettuce (2.35 mg g^{-1}) was observed in the treatment S_2F_1 , which involved the system "Lettuce + Moringa" combined with chemical fertilizer. On the other hand, the lowest chlorophyll b of lettuce (1.82 mg g^{-1}) was recorded in the treatment S_1F_2 , which included the production system "Lettuce sole" with cow dung application.

Table-4.54: Interaction Effect of Production Systems and Fertilizer Applications on Chlorophyll b (mg g^{-1})

Production Systems × Fertilizer Applications	Chlorophyll b (mg g^{-1})
S_1F_1	1.9500 a
S_1F_2	1.8200 a
S_1F_3	2.0600 a
S_1F_4	1.9100 a
S_2F_1	2.3500 a
S_2F_2	2.2100 a
S_2F_3	2.2933 a
S_2F_4	2.0400 a
CV (%)	13.63

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where, S_1F_1 =(Lettuce sole + Chemical fertilizer), S_1F_2 =(Lettuce sole + Cow dung), S_1F_3 =(Lettuce sole + Poultry manure), S_1F_4 =(Lettuce sole + No fertilizer), S_2F_1 =(Lettuce with Moringa + Chemical fertilizer), S_2F_2 =(Lettuce with Moringa + Cow dung), S_2F_3 =(Lettuce with Moringa + Poultry manure), S_2F_4 =(Lettuce with Moringa + No fertilizer.)

4.3.7 Carotene (mg g^{-1})

4.3.7.1 Effect of Production Systems

The results of the study, as depicted in (Table-4.55), showed that there were significant differences between the production systems in terms of their carotene (mg g^{-1}). The maximum carotene (1.64 mg g^{-1}) was observed in S_2 (Lettuce + Moringa) production system. On the other hand, the minimum carotene (1.48 mg g^{-1}) was found in S_1 (Lettuce sole) production system.

Table-4.55: Effect of Production Systems on Carotene (mg g^{-1})

Treatments (Production Systems)	Carotene (mg g^{-1})
S_1	1.4792 a
S_2	1.6350 a
CV (%)	19.47

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter (s) differ significantly.

Note: S_1 (Lettuce sole), S_2 (Lettuce with Moringa)

4.3.7.2 Fertilizer Effect

The Carotene of lettuce was influenced by different fertilizer applications in different agroforestry production systems (Table-4.56) presents the carotene obtained from various treatments. Among the treatments, the highest carotene of 1.94 mg g^{-1} was recorded in Treatment F_1 , where Chemical fertilizer was applied. Conversely, Treatment F_3 , which received poultry manuring applications, showed the lowest carotene of 1.32 mg g^{-1} . These findings indicate that the choice of fertilizer application significantly impacts the carotene of lettuce.

Table-4.56: Effect of Fertilizer Applications on Carotene (mg g^{-1})

Treatments (Fertilizers)	Carotene (mg g^{-1})
F_1	1.9400 a
F_2	1.3500 b
F_3	1.3233 b
F_4	1.6150 ab
CV (%)	19.47

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Note: F_1 (Chemical fertilizer), F_2 (Cow dung), F_3 (Poultry manure) and F_4 (No fertilizer).

4.3.7.3 Interaction Effect

The study investigated the impact of different production systems and fertilizer applications in different agroforestry production systems on the carotene of lettuce. The data presented in (Table-4.57) showed significant variations in lettuce carotene due to the interaction between production systems and fertilizer applications. Among the different treatment combinations, the highest carotene of lettuce (1.96 mg g^{-1}) was observed in the treatment S_2F_1 , which involved the production system "Lettuce + Moringa" combined with chemical fertilizer. On the other hand, the lowest carotene of lettuce (1.14 mg g^{-1}) was recorded in the treatment S_1F_2 , which included the production system "Lettuce sole" with cow dung application.

Table-4.57: Interaction Effect of Production Systems and Fertilizer Applications on Carotene (mg g^{-1})

Production Systems × Fertilizer Applications	Carotene (mg g^{-1})
S_1F_1	1.9200 a
S_1F_2	1.1400 a
S_1F_3	1.1767 a
S_1F_4	1.6800 a
S_2F_1	1.9600 a
S_2F_2	1.5600 a
S_2F_3	1.4700 a
S_2F_4	1.5500 a
CV (%)	19.47

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where, S_1F_1 =(Lettuce sole + Chemical fertilizer), S_1F_2 =(Lettuce sole + Cow dung), S_1F_3 =(Lettuce sole + Poultry manure), S_1F_4 =(Lettuce sole + No fertilizer), S_2F_1 =(Lettuce with Moringa + Chemical fertilizer), S_2F_2 =(Lettuce with Moringa + Cow dung), S_2F_3 =(Lettuce with Moringa + Poultry manure), S_2F_4 =(Lettuce with Moringa + No fertilizer.)

4.3.8 Ca (mg 100g⁻¹)

4.3.8.1 Effect of Production Systems

The results of the study, as depicted in (Table-4.58), showed that there were significant differences between the production systems in terms of their Ca (mg g⁻¹). The maximum Ca (577.20 mg 100g⁻¹) was observed in S₁ (Lettuce sole) production system. On the other hand, the minimum Ca (518.33 mg 100g⁻¹) was found in S₂ (Lettuce + Moringa) production system.

Table-4.58: Effect of Production Systems on Ca (mg 100g⁻¹)

Treatments (Systems)	Ca (mg 100g ⁻¹)
S ₁	577.20 a
S ₂	518.33 b
CV (%)	2.96

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter (s) differ significantly.

Note: S₁ (Lettuce sole), S₂ (Lettuce with Moringa)

4.3.8.2 Fertilizer effect

The Ca of lettuce was influenced by different fertilizer applications in different agroforestry production system (Table-4.59) presents the Ca obtained from various treatments. Among the treatments, the highest Ca of 598.81 mg 100g⁻¹ was recorded in Treatment F₃, where poultry manure was applied. Conversely, Treatment F₁, which received chemical fertilizer application, showed the lowest Ca of 476.14 mg 100g⁻¹. These findings indicate that the choice of fertilizer application significantly impacts the Ca of lettuce.

Table-4.59: Effect of Fertilizer Applications on Ca (mg 100g⁻¹)

Treatments (Fertilizers)	Ca (mg 100g ⁻¹)
F ₁	476.14 c
F ₂	597.15 a
F ₃	598.81 a
F ₄	518.96 b
CV (%)	2.96

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Note: F₁ (Chemical fertilizer), F₂ (Cow dung), F₃ (Poultry manure) and F₄ (No fertilizer).

4.3.8.3 Interaction Effect

The study investigated the impact of different production systems and fertilizer applications in different agroforestry production systems on the Ca of lettuce. The data presented in (Table-4.60) showed significant variations in lettuce Ca due to the interaction between production systems and fertilizer applications. Among the different treatment combinations, the highest Ca of lettuce (638.73 mg g^{-1}) were observed in two treatment S_1F_2 and S_1F_3 , which involved the production system "Lettuce sole" combined with cow dung and poultry manuring respectively. On the other hand, the lowest Ca of lettuce (400 mg g^{-1}) was recorded in the treatment S_2F_1 , which included the production system "Lettuce + Moringa" with chemical fertilizer application.

Table-4.60: Interaction Effect of Production Systems and Fertilizer Applications on Ca ($\text{mg } 100\text{g}^{-1}$)

Production Systems × Fertilizer Applications	Ca ($\text{mg } 100\text{g}^{-1}$)
S_1F_1	552.28 b
S_1F_2	638.73 a
S_1F_3	638.73 a
S_1F_4	479.04 c
S_2F_1	400.00 d
S_2F_2	555.56 b
S_2F_3	558.88 b
S_2F_4	558.88 b
CV%	2.96

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where, S_1F_1 =(Lettuce sole + Chemical fertilizer), S_1F_2 =(Lettuce sole + Cow dung), S_1F_3 =(Lettuce sole + Poultry manure), S_1F_4 =(Lettuce sole + No fertilizer), S_2F_1 =(Lettuce with Moringa + Chemical fertilizer), S_2F_2 =(Lettuce with Moringa + Cow dung), S_2F_3 =(Lettuce with Moringa + Poultry manure), S_2F_4 =(Lettuce with Moringa + No fertilizer.)

4.3.9 Mg (mg 100g⁻¹)

4.3.9.1 Effect of Production Systems

The results of the study, as depicted in (Table-4.61), showed that there were significant differences between the production systems in terms of their Mg (mg 100g⁻¹). The maximum Mg (289.93 mg 100g⁻¹) was observed in S₁ (Lettuce sole) production system. On the other hand, the minimum Mg (266 mg 100g⁻¹) was found in S₂ (Lettuce + Moringa) production system.

Table-4.61: Effect of Production Systems on Mg (mg 100g⁻¹)

Treatments (Production Systems)	Mg (mg 100g ⁻¹)
S ₁	289.93 a
S ₂	266.00 b
CV (%)	1.96

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter (s) differ significantly.

Note: S₁ (Lettuce sole), S₂ (Lettuce with Moringa)

4.3.9.2 Fertilizer Effect

The Mg of lettuce was influenced by different fertilizer applications in different agroforestry production system (Table-4.62) presents the Mg obtained from various treatments. Among the treatments, the highest Mg of (314.71 mg 100g⁻¹) was recorded in Treatment F₃, where poultry manure was applied. Conversely, Treatment F₁, which received chemical fertilizer application, showed the lowest Mg of (241.23 mg 100g⁻¹). These findings indicate that the choice of fertilizer application significantly impacts the Mg of lettuce.

Table-4.62: Effect of Fertilizer Applications on Mg (mg 100g⁻¹)

Treatments (Fertilizers)	Mg (mg 100g ⁻¹)
F ₁	241.23 b
F ₂	265.43 c
F ₃	314.71 a
F ₄	290.50 b
CV (%)	1.96

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Note: F₁ (Chemical fertilizer), F₂ (Cow dung), F₃ (Poultry manure) and F₄ (No fertilizer).

4.3.9.3 Interaction Effect

The study investigated the impact of different production systems and fertilizer applications in different agroforestry production system on the Mg of lettuce. The data presented in (Table-4.63) showed significant variations in lettuce Mg due to the interaction between production systems and fertilizer applications. Among the different treatment combinations, the highest Mg of lettuce (387.33 mg 100g⁻¹) was observed in the treatment S₁F₃, which involved the production system "Lettuce sole" combined with poultry manure. On the other hand, the lowest Mg of lettuce (191.38 mg 100g⁻¹) was recorded in the treatment S₁F₁, which included the production system "Lettuce sole" with chemical fertilizer application.

Table-4.63: Interaction Effect of Production Systems and Fertilizer Applications on Mg (mg 100g⁻¹)

Production Systems × Fertilizer Applications	Mg (mg 100g⁻¹)
S ₁ F ₁	191.38 e
S ₁ F ₂	242.08 d
S ₁ F ₃	387.33 a
S ₁ F ₄	338.91 b
S ₂ F ₁	291.08 c
S ₂ F ₂	288.77 c
S ₂ F ₃	242.08 d
S ₂ F ₄	242.08 d
CV (%)	1.96

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where, S₁F₁=(Lettuce sole + Chemical fertilizer),S₁F₂=(Lettuce sole + Cow dung),S₁F₃=(Lettuce sole + Poultry manure),S₁F₄ =(Lettuce sole + No fertilizer),S₂F₁ =(Lettuce with Moringa + Chemical fertilizer),S₂F₂ =(Lettuce with Moringa + Cow dung),S₂F₃ =(Lettuce with Moringa + Poultry manure), S₂F₄=(Lettuce with Moringa + No fertilizer.)

4.3.10 Available sodium (Na) (mg 100g⁻¹)

4.3.10.1 Effect of Production Systems

The results of the study, as depicted in (Table-4.64), showed that there were significant differences between the production systems in terms of their Na (mg g⁻¹) contents in lettuce leaf. The maximum Na (102.42 mg 100g⁻¹) was observed in S₁ (Lettuce sole) production system. On the other hand, the minimum Na (92.64 mg 100g⁻¹) was found in S₂ (Lettuce + Moringa) production system.

Table-4.64: Effect of Production Systems on Na (mg 100g⁻¹)

Treatments (Production Systems)	Na (mg 100g ⁻¹)
S ₁	102.42 a
S ₂	92.64 b
CV (%)	3.83

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter (s) differ significantly.

Note: S₁ (Lettuce sole), S₂ (Lettuce with Moringa)

4.3.10.2 Fertilizer Effect on Na availability

The leaf Na of lettuce was influenced by different fertilizer applications in different agroforestry production systems (Table-4.65.) Among the treatments, the highest Na (110.81 mg 100g⁻¹) was recorded in Treatment F₃, where poultry manure was applied. Conversely, Treatment F₁, which received chemical fertilizer application, showed the lowest Na of (86.64 mg 100g⁻¹). These findings indicate that the choice of fertilizer application significantly impacts the Na of lettuce.

Table-4.65: Effect of Fertilizer Applications on Na (mg 100g⁻¹)

Treatments (Fertilizers)	Na (mg 100g ⁻¹)
F ₁	86.64 c
F ₂	99.31 b
F ₃	110.81 a
F ₄	93.37 b
CV (%)	3.83

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Note: F₁ (Chemical fertilizer), F₂ (Cow dung), F₃ (Poultry manure) and F₄ (No fertilizer).

4.3.10.3 Interaction Effect

The study investigated the impact of different production systems and fertilizer applications in different agroforestry production system on the Na of lettuce. The data presented in (Table-4.66) showed significant variations in lettuce Na due to the interaction between production systems and fertilizer applications. Among the different treatment combinations, the highest Na of lettuce (112.05 mg 100g⁻¹) was observed in the treatment S₁F₃, which involved the production system "Lettuce sole" combined with poultry manure. On the other hand, the lowest Na of lettuce (74.85 mg 100g⁻¹) was recorded in the treatment S₂F₁, which included the production system "Lettuce + Moringa" with chemical fertilizer application.

Table-4.66: Interaction Effect of Production Systems and Fertilizer Applications on Na (mg 100g⁻¹)

Production Systems × Fertilizer Applications	Na (mg 100g⁻¹)
S ₁ F ₁	98.43 c
S ₁ F ₂	99.60 bc
S ₁ F ₃	112.05 a
S ₁ F ₄	99.59 bc
S ₂ F ₁	74.85 e
S ₂ F ₂	99.01 bc
S ₂ F ₃	109.56 ab
S ₂ F ₄	87.15 d
CV (%)	3.83

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where, S₁F₁=(Lettuce sole + Chemical fertilizer),S₁F₂=(Lettuce sole + Cow dung),S₁F₃=(Lettuce sole + Poultry manure),S₁F₄=(Lettuce sole + No fertilizer),S₂F₁=(Lettuce with Moringa + Chemical fertilizer),S₂F₂=(Lettuce with Moringa + Cow dung),S₂F₃=(Lettuce with Moringa + Poultry manure), S₂F₄=(Lettuce with Moringa + No fertilizer.)

4.3.11 K (mg 100g⁻¹)

4.3.11.1 Effect of Production Systems

The results of the study, as depicted in (Table-4.67), showed that there were significant differences between the production systems in terms of their K. The maximum K (248.49 mg 100g⁻¹) was observed in S₁ (Lettuce sole) production system. On the other hand, the minimum K (192.61 mg 100g⁻¹) was found in S₂ (Lettuce + Moringa) production system.

Table-4.67: Effect of Production Systems on K (mg 100g⁻¹)

Treatments (Production Systems)	K (mg 100g ⁻¹)
S ₁	248.49 a
S ₂	192.61 b
CV (%)	4.80

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter (s) differ significantly.

Note: S₁ (Lettuce sole), S₂ (Lettuce with Moringa)

4.3.11.2 Fertilizer Effect

The K of lettuce was influenced by different fertilizer applications in different agroforestry production system (Table-4.68) presents the K obtained from various treatments. Among the treatments, the highest K of (286.36 mg 100g⁻¹) was recorded in Treatment F₃, where poultry manure was applied. Conversely, Treatment F₁, which received chemical fertilizer application, showed the lowest K of (173.45 mg 100g⁻¹).

These findings indicate that the choice of fertilizer application significantly impacts the K of lettuce.

Table-4.68: Effect of Fertilizer Applications on K (mg 100g⁻¹)

Treatments (Fertilizers)	K (mg 100g ⁻¹)
F ₁	173.45 c
F ₂	248.09 b
F ₃	286.36 a
F ₄	174.30 c
CV (%)	4.80

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Note: F₁ (Chemical fertilizer), F₂ (Cow dung), F₃ (Poultry manure) and F₄ (No fertilizer).

4.3.11.3 Interaction Effect

The study investigated the impact of different production systems and fertilizer applications in different agroforestry production system on the K of lettuce. The data presented in (Table-4.69) showed significant variations in lettuce K due to the interaction between production systems and fertilizer applications. Among the different treatment combinations, the highest K of lettuce (323.71 mg 100g⁻¹) was observed in the treatment S₁F₃, which involved the production system "Lettuce sole" combined with poultry manure. On the other hand, the lowest K of lettuce (124.50 mg 100g⁻¹) was recorded in the treatment S₂F₄, which included the production system "Lettuce + Moringa" without any fertilizer application.

Table-4.69: Interaction Effect of Production Systems and Fertilizer Applications on K (mg 100g⁻¹)

Production Systems × Fertilizer Applications	K (mg 100g⁻¹)
S ₁ F ₁	172.24 d
S ₁ F ₂	273.90 b
S ₁ F ₃	323.71 a
S ₁ F ₄	224.10 c
S ₂ F ₁	174.65 d
S ₂ F ₂	222.27 c
S ₂ F ₃	249.00 bc
S ₂ F ₄	124.50 e
CV (%)	4.80

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where, S₁F₁=(Lettuce sole + Chemical fertilizer),S₁F₂=(Lettuce sole + Cow dung),S₁F₃=(Lettuce sole + Poultry manure),S₁F₄ =(Lettuce sole + No fertilizer),S₂F₁ =(Lettuce with Moringa + Chemical fertilizer),S₂F₂ =(Lettuce with Moringa + Cow dung),S₂F₃ =(Lettuce with Moringa + Poultry manure), S₂F₄=(Lettuce with Moringa + No fertilizer.)

4.3.12 P (mg 100g⁻¹)

4.3.12.1 Effect of Production Systems

The results of the study, as depicted in (Table-4.70), showed that there were significant differences between the production systems in terms of their P. The maximum P (33.34 mg 100g⁻¹) was observed in S₁ (Lettuce sole) production system. On the other hand, the minimum P (27.36 mg 100g⁻¹) was found in S₂ (Lettuce + Moringa) production system.

Table-4.70: Effect of Production Systems on P (mg 100g⁻¹)

Treatments (Production Systems)	P (mg 100g ⁻¹)
S ₁	33.34 a
S ₂	27.36 b
CV%	5.98%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter (s) differ significantly.

Note: S₁ (Lettuce sole), S₂ (Lettuce with Moringa)

4.3.12.2 Fertilizer Effect

The P of lettuce was influenced by different fertilizer applications in different agroforestry production system (Table-4.71) presents the P obtained from various treatments. Among the treatments, the highest P of (36.40 mg 100g⁻¹) was recorded in the treatment F₄, where no fertilizer was applied. Conversely, Treatment F₃, which received poultry manure application, showed the lowest P of (25.77 mg 100g⁻¹).

These findings indicate that the choice of fertilizer application significantly impacts the P of lettuce.

Table-4.71: Effect of Fertilizer Applications on P (mg 100g⁻¹)

Treatments (Fertilizers)	P (mg 100g ⁻¹)
F ₁	30.29 b
F ₂	28.93 b
F ₃	25.77 c
F ₄	36.40 a
CV (%)	5.98%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Note: F₁ (Chemical fertilizer), F₂ (Cow dung), F₃ (Poultry manure) and F₄ (No fertilizer).

4.3.12.3 Interaction Effect

The study investigated the impact of different production systems and fertilizer applications in different agroforestry production systems on the P of lettuce. The data presented in (Table-4.72) showed significant variations in lettuce P due to the interaction between production systems and fertilizer applications. Among the different treatment combinations, the highest P of lettuce (41.13 mg 100g⁻¹) was observed in the treatment S₂F₄, which involved the production system "Lettuce + Moringa" combined with no fertilizer. On the other hand, the lowest P of lettuce (20.84 mg 100g⁻¹) was recorded in the treatment S₂F₁, which included the production system "Lettuce + Moringa" with chemical fertilizer application.

Table-4.72: Interaction Effect of Production Systems and Fertilizer Applications on P (mg 100g⁻¹)

Production Systems × Fertilizer Applications	P (mg 100g⁻¹)
S ₁ F ₁	39.74 a
S ₁ F ₂	32.82 b
S ₁ F ₃	29.12 bc
S ₁ F ₄	31.66 b
S ₂ F ₁	20.84 d
S ₂ F ₂	25.04 cd
S ₂ F ₃	22.42 d
S ₂ F ₄	41.13 a
CV%	5.98%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where, S₁F₁=(Lettuce sole + Chemical fertilizer),S₁F₂=(Lettuce sole + Cow dung),S₁F₃=(Lettuce sole + Poultry manure),S₁F₄ =(Lettuce sole + No fertilizer),S₂F₁ =(Lettuce with Moringa + Chemical fertilizer),S₂F₂ =(Lettuce with Moringa + Cow dung),S₂F₃ =(Lettuce with Moringa + Poultry manure), S₂F₄=(Lettuce with Moringa + No fertilizer.)

4.3.13 Temperature in (°c)

4.3.13.1 Effect of Production Systems

The results of the study, as depicted in (Table-4.73), showed that there were significant differences between the production systems in terms of their temperature in (°c). The maximum temperature in (36.82 °c) was observed in S₁ (Lettuce sole) production system. On the other hand, the minimum (32.93 °c) was found in S₂ (Lettuce + Moringa) production system.

Table-4.73: Effect of Production Systems on Temperature in (°c).

Treatments (Production Systems)	Temperature in (°c).
S ₁	36.82 a
S ₂	32.93 b
CV%	5.05%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter (s) differ significantly.

Note: S₁ (Lettuce sole), S₂ (Lettuce with Moringa)

4.3.13.2 Fertilizer effect

The temperature in (°c) of lettuce was influenced by different fertilizer applications in different agroforestry production systems (Table-4.74) presents the temperature in (°c) obtained from various treatments. Among the treatments, the highest temperature in (°c) of (35.57 °c) was recorded in Treatment F₄, where no fertilizer was applied. Conversely, Treatment F₁, which received chemical fertilizer application, showed the lowest temperature in (°c) of (34.19 °c).

These findings indicate that the choice of fertilizer application significantly impacts the P of lettuce.

Table-4.74: Effect of Fertilizer Applications on Temperature in (°c)

Treatments (Fertilizers)	Temperature in (°c)
F ₁	34.19 a
F ₂	34.64 a
F ₃	35.09 a
F ₄	35.57 a
CV (%)	5.05%

In a column, figure having similar letter(s) do not differ significantly.

Note: F₁ (Chemical fertilizer), F₂ (Cow dung), F₃ (Poultry manure) and F₄ (No fertilizer).

4.3.13.3 Interaction Effect

The study investigated the impact of different production systems and fertilizer applications in different agroforestry production systems on the temperature in (°c) of lettuce. The data presented in (Table-4.75) showed significant variations in lettuce temperature in (°c) due to the interaction between production systems and fertilizer applications. Among the different treatment combinations, the highest temperature in (°c) of lettuce (38.08 °c) was observed in the treatment S₁F₄, which involved the production system "Lettuce sole" combined with no fertilizer. On the other hand, the lowest temperature in (°c) of lettuce (32.67 °c) was recorded in the treatment S₂F₂, which included the production system "Lettuce + Moringa" with cow dung application.

Table-4.75: Interaction Effect of Production Systems and Fertilizer Applications on Temperature in (°c)

Production Systems × Fertilizer Applications	Temperature in (°c)
S ₁ F ₁	35.58 ab
S ₁ F ₂	36.61 ab
S ₁ F ₃	37.01 ab
S ₁ F ₄	38.08 a
S ₂ F ₁	32.80 b
S ₂ F ₂	32.67 b
S ₂ F ₃	33.17 ab
S ₂ F ₄	33.07 b
CV%	5.05%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where, S₁F₁=(Lettuce sole + Chemical fertilizer),S₁F₂=(Lettuce sole + Cow dung),S₁F₃=(Lettuce sole + Poultry manure),S₁F₄ =(Lettuce sole + No fertilizer),S₂F₁ =(Lettuce with Moringa + Chemical fertilizer),S₂F₂ =(Lettuce with Moringa + Cow dung),S₂F₃ =(Lettuce with Moringa + Poultry manure), S₂F₄=(Lettuce with Moringa + No fertilizer.)

4.3.14 Temperature out (°c)

4.3.14.1 Effect of Production Systems

The results of the study, as depicted in (Table-4.76), showed that there were significant differences between the production systems in terms of their temperature out (°c). The maximum temperature out (29.09 °c) was observed in S₁ (Lettuce sole) production system. On the other hand, the minimum (28.87 °c) was found in S₂ (Lettuce + Moringa) production system.

Table-4.76: Effect of Production Systems on Temperature out (°c).

Treatments (Production Systems)	Temperature out (°c).
S ₁	29.09 a
S ₂	28.87 a
CV%	5.09%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter (s) differ significantly.

Note: S₁ (Lettuce sole), S₂ (Lettuce with Moringa)

4.3.14.2 Fertilizer Effect

The temperature out (°c) of lettuce was influenced by different fertilizer applications in different agroforestry production system (Table-4.77) presents the temperature out (°c) obtained from various treatments. Among the treatments, the highest temperature out (°c) of (29.32 °c) was recorded in Treatment F₃, where poultry manure was applied. Conversely, Treatment F₂, which received cow dung application, showed the lowest temperature out (°c) of (28.28 °c).

These findings indicate that the choice of fertilizer application significantly impacts the temperature out (°c) of lettuce.

Table-4.77: Effect of Fertilizer Applications on Temperature out (°c)

Treatments (Fertilizers)	Temperature out (°c)
F ₁	29.05 a
F ₂	28.28 a
F ₃	29.32 a
F ₄	29.27 a
CV (%)	5.09

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Note: F₁ (Chemical fertilizer), F₂ (Cow dung), F₃ (Poultry manure) and F₄ (No fertilizer).

4.3.14.3 Interaction Effect

The study investigated the impact of different production systems and fertilizer applications in different agroforestry production system on the temperature out (°c) of lettuce. The data presented in (Table-4.78) showed significant variations in lettuce temperature out (°c) due to the interaction between production systems and fertilizer applications. Among the different treatment combinations, the highest temperature out (°c) of lettuce (30.20 °c) was observed in the treatment S₁F₃, which involved the production system "Lettuce sole" combined with poultry manure. On the other hand, the lowest temperature out (°c) of lettuce (27.80 °c) was recorded in the treatment S₁F₂, which included the production system "Lettuce sole" with cow dung application.

Table-4.78: Interaction Effect of Production Systems and Fertilizer Applications on Temp. Out (°c)

Production Systems × Fertilizer Applications	Temperature out (°c)
S ₁ F ₁	29.20 a
S ₁ F ₂	27.80 a
S ₁ F ₃	30.20 a
S ₁ F ₄	29.17 a
S ₂ F ₁	28.90 a
S ₂ F ₂	28.77 a
S ₂ F ₃	28.43 a
S ₂ F ₄	29.37 a
CV (%)	5.09

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where, S₁F₁=(Lettuce sole + Chemical fertilizer),S₁F₂=(Lettuce sole + Cow dung),S₁F₃=(Lettuce sole + Poultry manure),S₁F₄ =(Lettuce sole + No fertilizer),S₂F₁ =(Lettuce with Moringa + Chemical fertilizer),S₂F₂ =(Lettuce with Moringa + Cow dung),S₂F₃ =(Lettuce with Moringa + Poultry manure), S₂F₄=(Lettuce with Moringa + No fertilizer.)

4.3.15 Relative Humidity (%)

4.3.15.1 Effect of Production Systems

The results of the study, as depicted in (Table-4.79), showed that there were significant differences between the production systems in terms of their relative humidity (%). The maximum relative humidity (37.25%) was observed in S₂ (Lettuce + Moringa) production system. On the other hand, the minimum (33.08%) was found in S₁ (Lettuce sole) production system.

Table-4.79: Effect of Production Systems on Relative Humidity (%)

Treatments (Production Systems)	Relative humidity (%)
S ₁	33.08 b
S ₂	37.25 a
CV%	5.83%

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter (s) differ significantly.

Note: S₁ (Lettuce sole), S₂ (Lettuce with Moringa)

4.3.15.2 Fertilizer Effect

The relative humidity (%) of lettuce was influenced by different fertilizer applications in different agroforestry production system (Table-4.80) presents the relative humidity (%) obtained from various treatments. Among the treatments, the highest relative humidity (%) of (35.67%) was recorded in Treatment F₄, where no fertilizer was applied. Conversely, Treatment F₃, which received poultry manure application, showed the lowest relative humidity (%) of (34.50%).

These findings indicate that the choice of fertilizer application significantly impacts the temperature out (°c) of lettuce.

Table-4.80: Effect of Fertilizer Applications on Relative Humidity (%)

Treatments (Fertilizers)	Relative Humidity (%)
F ₁	35.17 a
F ₂	35.33 a
F ₃	34.50 a
F ₄	35.67 a
CV (%)	5.83%

In a column, figures having similar letter(s) do not differ significantly.

Note: F₁ (Chemical fertilizer), F₂ (Cow dung), F₃ (Poultry manure) and F₄ (No fertilizer).

4.3.15.3 Interaction Effect

The study investigated the impact of different production systems and fertilizer applications in different agroforestry production system on the relative humidity (%) of lettuce. The data presented in (Table-4.81) showed significant variations in lettuce relative humidity (%) due to the interaction between production systems and fertilizer applications. Among the different treatment combinations, the highest relative humidity (%) of lettuce (37.67%) were observed in three treatments i.e. S₂F₁, S₂F₂ and S₂F₄, which involved the system "Lettuce + Moringa" combined with chemical fertilizer, cow dung and no fertilizer respectively. On the other hand, the lowest of lettuce relative humidity (32.67%) was recorded in the treatment S₁F₁, which included the production system "Lettuce sole" with chemical fertilizer application.

Table-4.81: Interaction Effect of Production Systems and Fertilizer Applications on Relative humidity (%)

Production Systems × Fertilizer Applications	Relative humidity (%)
S ₁ F ₁	32.67 a
S ₁ F ₂	33.00 a
S ₁ F ₃	33.00 a
S ₁ F ₄	33.67 a
S ₂ F ₁	37.67 a
S ₂ F ₂	37.67 a
S ₂ F ₃	36.00 a
S ₂ F ₄	37.67 a
CV (%)	5.83

In a column, figures having similar letter(s) do not differ significantly.

Where, S₁F₁ = (Lettuce sole + Chemical fertilizer), S₁F₂ = (Lettuce sole + Cow dung), S₁F₃ = (Lettuce sole + Poultry manure), S₁F₄ = (Lettuce sole + No fertilizer), S₂F₁ = (Lettuce with Moringa + Chemical fertilizer), S₂F₂ = (Lettuce with Moringa + Cow dung), S₂F₃ = (Lettuce with Moringa + Poultry manure), S₂F₄ = (Lettuce with Moringa + No fertilizer.)

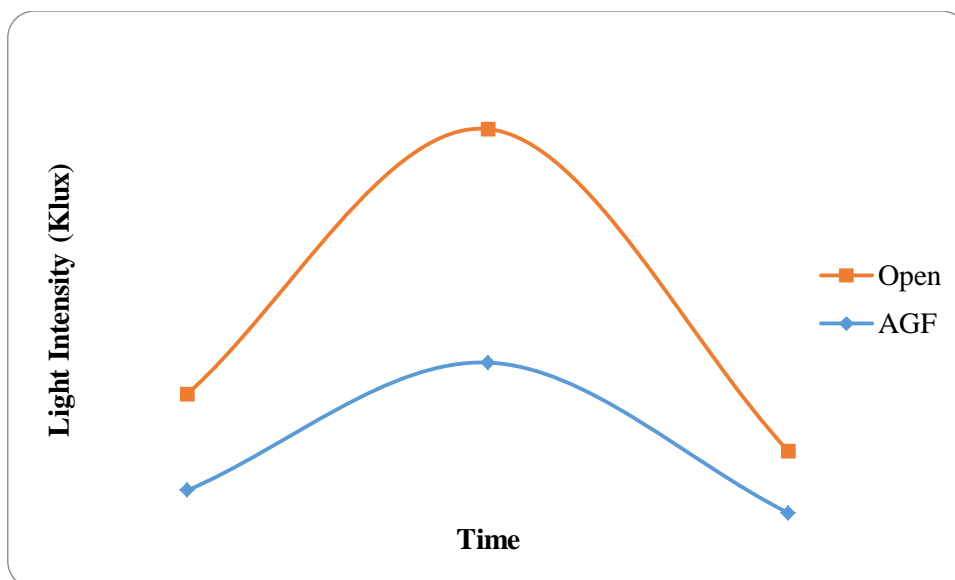
4.4 Light Intensity (Klux)

4.4.1 Effect of Production Systems

The study investigated the impact of light intensity on photosynthesis in both open and moringa based agroforestry production systems. The results, presented in Figure-4.1, demonstrated significant differences in light intensity (klux) between the two production systems at different times during the day (9 am, 1 pm, and 4 pm). Specifically, the highest light intensity was recorded at 1 pm, with 63.10 klux in the open area and 52.96 klux in the moringa based agroforestry production system. On the other hand, the lowest light intensity was observed at 4 pm, with 16.69 klux in the open area and 12.33 klux in the agroforestry production system.

Light intensity is a crucial factor for photosynthesis, the process by which Plants convert light energy into chemical energy and synthesize organic compounds. The significant difference in light intensity between the open and agroforestry production systems indicates that the presence of moringa trees in the agroforestry production system affects light availability for understory vegetable like lettuce. The highest light intensity at 1 pm suggests that this time of the day is the most favorable for photosynthesis in both the open and agroforestry production systems. However, the open area generally received more light compared to the agroforestry production system. This difference is likely due to the shading effect of the moringa trees on the understory vegetable during certain times of the day. In an agroforestry production system as the distance increases from the tree base, the availability of Photosynthetic Active Radiation (PAR) also increases.

PAR is the part of the light spectrum that vegetable can use for photosynthesis. At larger distances from tree bases, the competition for below-ground resources, such as water and nutrients, is reduced, creating a more favorable environment for lettuce leaves growth. Moringa, being an agroforestry tree species with small leaf characteristics, allows more light to reach the understory vegetable. This increased light availability promotes the growth of lettuce leaves, potentially leading to higher yields similar to those in open systems. The findings suggest that incorporating moringa trees in agroforestry production systems can enhance light distribution and optimize photosynthetic activity for the understory vegetable.



Treatment	9.00 am	1.00 pm	4.00 pm
Open	26.04 a	63.10 a	16.69 a
AGF	18.42 b	52.96 b	12.33 b

Figure-4.1: Light Intensity (Klux) in Open and AGF Condition

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

4.4.2 Month Wise Effect

The results presented in Table-4.82 revealed that there was significant difference among month wise light intensity. During the growth period of lettuce the highest average light intensity was in the month of March (67.94 klux at 1 pm.) and the lowest average light intensity was in the month of January (8.44 klux at 4pm.). During winter light intensity is lower than summer season. Light is the primary limiting factor with respect to the growth and development of vegetables in agroforestry systems (Surki *et al.* 2020).

Table-4.82: Month Wise Light Intensity (Klux) During Growth Period

Month	9:00 AM	1:00 PM	4:00 PM
December	11.39 c	56 bc	9.62 b
January	8.86 c	49.71 c	8.44 b
February	17.73 b	58.45 b	17.36 a
March	50.97 a	67.94 a	22.64 a

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

4.4.3 Month Wise Effect in Production Systems

The analysis of variance revealed that the average light intensity was significantly influenced by production systems and growing month. In case of the interaction effect the highest light intensity was in month of March at open system at 1pm (75.62 klux) and the lowest light intensity was in month of January at moringa based agroforestry production system at 4pm (7.37 klux). It has been revealed from the experimental result that the highest light intensity at moringa based agroforestry production system was in month of March (60.26 klux), at this time the leaves of lettuce become mature for harvesting. Rather moringa leaves fall in winter sometimes. So, lettuce can be grown in partial shade of moringa-based agroforestry production systems without enduring significant yield losses. The results are consistent with the study of Haq *et al.* (2022) who conducted research under moringa based agroforestry production system.

Table-4.83. Month Wise Light Intensity in Open and AGF Condition

Treatment	9:00 AM	1:00 PM	4:00 PM
open/Dec	12.11 de	57.40 bc	10.20 cd
open/Jan	9.62 de	54.63 bc	9.51 d
open/Feb	19.76 c	64.74 ab	21.45 ab
open/March	62.70 a	75.62 a	25.63 a
AGF/Dec	10.67 de	54.61 bc	9.04 d
AGF/Jan	8.09 e	44.80 c	7.37 d
AGF/Feb	15.69 cd	52.16 bc	13.27 bcd
AGF/March	39.24 b	60.26 b	19.65 abc

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

4.5 Economic Analysis of Lettuce

Profitability of growing lettuce as inter-crop in moringa based agroforestry production system was calculated based on local market rate prevailed during experimentation. The cost of production of lettuce and cost of production of tree Plantation and management of trees have been summarized in Appendix-IV. The return of produce and the profit per taka i.e. Benefit Cost Ratio (BCR) have also been presented in (Table-4.84).

4.5.1 Total Cost of Production

The values in (Table-4.84) indicated that the total cost of production was maximum (126039 tk/ha) in those plots where lettuce production system (Lettuce + Moringa) was cultivated with chemical fertilizer application under moringa based agroforestry production system (S_2F_1), whereas the minimum cost of production (96659 tk/ha) was recorded from lettuce production system (lettuce sole) with no fertilizer application (S_1F_4) under open production system. The maximum cost of production observed in S_2F_1 might be due to the seed cost which was varied from production system to production system and for the cost of chemical fertilizers. However, the detail cost of production is presented in Appendix-IV.

4.5.2 Gross Return

Gross return is an important indicator whether vegetable cultivation is profitable or not. It was varying with the treatment combinations of lettuce production under different agroforestry production systems. The values in (Table-4.84) indicated that the highest value of gross return (557000 tk/ha) was obtained from S_2F_2 (Lettuce with Moringa + Cow dung), and the lowest value of gross return (380600 tk/ha) was obtained from S_1F_4 (Lettuce sole + No fertilizer).

4.5.3 Net Return

Results presented in the (Table-4.84) showed that net return (443391 tk/ha) was comparatively higher in S_2F_2 (Lettuce with Moringa + Cow dung). At the same time, the lowest net return (277686 tk/ha) was received from S_1F_2 (Lettuce sole + Cow dung) under open production system.

4.5.4 Benefit-Cost Ratio (BCR)

The values (Table-4.84) indicate that the highest benefit-cost ratio (5.07) was recorded from S_2F_4 (Lettuce with Moringa) production system with no fertilizer application. On the other hand, the lowest benefit-cost ratio (3.48) was observed from S_1F_2 (Lettuce sole) with Cow dung. This may be because of production system ability of (Lettuce with Moringa) to give profitable yield of lettuce under moringa based agroforestry production system without fertilizer applications. Moreover, moringa leaves residues may add organic nutrients to the soil. So, Lettuce production system with the handsome yield of moringa tree give a higher benefit as an agroforestry combination. Thus, it may be

advocated that such type of speculation will be beneficial to the farmer as because such project provides cash money to the farmer and gradually can enrich the soil nutritionally.

Table-4.84: Economics Analysis of Lettuce Production under Moringa Based Agroforestry Production System (per ha per Plant season)

Treatment	Return (Tk./ha)		Gross Return (Tk./ha)	Total Cost of Production (Tk./ha)	Net Return (Tk./ha)	BCR
	Moringa	Lettuce				
S ₁ F ₁	200000	241800	441800	124344	317456	3.55
S ₁ F ₂	200000	189600	389600	111914	277686	3.48
S ₁ F ₃	200000	203400	403400	106829	296571	3.78
S ₁ F ₄	200000	180600	380600	96659	283941	3.94
S ₂ F ₁	200000	324600	524600	126039	398561	4.16
S ₂ F ₂	200000	357000	557000	113609	443391	4.90
S ₂ F ₃	200000	301200	501200	108524	392676	4.62
S ₂ F ₄	200000	298200	498200	98354	399846	5.07

Note: Number of moringa tree was 625/ha, yield of each moringa tree was 20kg/tree and price of moringa was 48tk/kg. For Plant season (only lettuce cultivation period i.e. 4 months) were considered. Tree yield output was divided by 3 for the Plant season output cultivation. Price of lettuce was 80tk/kg.

Where, S₁F₁=(Lettuce sole + Chemical fertilizer),S₁F₂=(Lettuce sole + Cow dung),S₁F₃=(Lettuce sole + Poultry manure),S₁F₄=(Lettuce sole + No fertilizer),S₂F₁=(Lettuce with Moringa + Chemical fertilizer),S₂F₂ = (Lettuce with Moringa + Cow dung),S₂F₃=(Lettuce with Moringa + Poultry manure), S₂F₄=(Lettuce with Moringa + No fertilizer.)

CHAPTER V

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary

Lettuce (*Lactuca sativa*) is an annual Plant of the family Asteraceae, commonly grown as a leaf vegetable and occasionally for its stem and seeds. It is predominantly used in salads but also features in soups, sandwiches, wraps, and can be grilled. One variety, celtuce (asparagus lettuce), can be consumed raw or cooked. In Bangladesh, lettuce is a significant vegetable, used for culinary and medicinal purposes. Enhancing lettuce yield and quality is crucial for improving production efficiency, particularly in Northern Bangladesh, where farmers typically use available cultivars with minimal or no fertilizer application. Due to limited agricultural land, incorporating lettuce into an agroforestry system can optimize land use and meet national demand. This study aimed to evaluate the effects of different production systems and fertilizer applications on lettuce growth and yield in the research field of Hajee Mohammad Danesh Science and Technology University, Dinajpur. Conducted from December 2023 to March 2024, the experiment used a 2x4 factorial design with two production systems (Lettuce sole and Lettuce with Moringa) and four fertilizer treatments (Chemical fertilizers, Cow dung, Poultry manure, and No fertilizer). Data on growth, yield, and quality were analyzed using ANOVA and Tukey HSD tests. Results indicated significant differences in growth and yield based on production system and fertilizer treatment. The highest Plant height at 60 days after sowing (DAS) was observed in the Lettuce with Moringa system (30.39 cm), while the Lettuce sole system had the lowest (19.05 cm). The Chemical fertilizer treatment resulted in the tallest Plants (26.55 cm), whereas the No fertilizer treatment produced the shortest (22.91 cm). Interaction effects showed that Lettuce with Moringa and Poultry manure treatment yielded the tallest Plants (31.80 cm), while Lettuce sole with No fertilizer had the shortest (17.48 cm). Leaf number, length, breadth, and weight were also highest in the Lettuce with Moringa system and the Chemical fertilizer treatment. The highest number of leaves per Plant (24.23) and plot (1452.5) were in the Lettuce with Moringa system, with Chemical fertilizer yielding the maximum leaves per Plant (23.70) and plot (1422). Leaf weight per Plant and plot was highest in the Lettuce with Moringa system and the Chemical fertilizer treatment. Yield per Plant and plot was similarly highest in the Lettuce with Moringa system and Chemical fertilizer treatment, with the highest

yield observed in the Lettuce with Moringa and Chemical fertilizer combination (28.57 t ha⁻¹). Quality characteristics such as moisture content, dry matter, protein, ash, chlorophyll a and b, carotene, and mineral content (Ca, Mg, Na, K, S) varied significantly across treatments. The Lettuce with Moringa system generally produced lettuce with higher moisture content and chlorophyll levels, while the Lettuce sole system resulted in higher dry matter, protein, and mineral content. Chemical fertilizer application enhanced chlorophyll and carotene levels but reduced mineral content compared to organic fertilizers. The interaction effects revealed that the combination of Lettuce with Moringa and Chemical fertilizer generally yielded the highest chlorophyll and carotene content, while Lettuce sole with organic fertilizers (Cow dung and Poultry manure) enhanced mineral content. The study underscores the importance of integrating agroforestry systems and appropriate fertilizer application to improve lettuce productivity and quality, suggesting that organic fertilizers benefit soil health and human health. The findings advocate for optimizing fertilizer use in agroforestry systems to enhance the overall yield and marketability of lettuce in Bangladesh.

5.2 Conclusion

The findings of the present investigation indicated that diversification of farming system and growing lettuce as ground layers crops in moringa tree is a viable option for increasing income of farmers. The moringa orchard was suitable for lettuce cultivation because moringa is a deciduous and light canopy tree. The presence of the moringa tree canopy did not influence so much in growth and yield of lettuce. The use of chemical fertilizers proved to be the most effective in increasing yield across both systems, but the eco-friendly and cost-effective nature of the "Lettuce + Moringa" system with cow dung or poultry manure even no fertilizer application presents a sustainable option for farmers. Moreover, in economic context, Moringa + lettuce-based agroforestry systems was most beneficial as it ensure higher returns than the other systems. Therefore, these findings suggest that agroforestry systems, specifically integrating lettuce with moringa, can be a viable and beneficial approach for improving lettuce production in Bangladesh.

5.3 Recommendations

1. To get more production of lettuce to fulfil the required demand in the country lettuce production under different agroforestry production system can be feasible. The lettuce production system “Lettuce with Moringa” grown at the floor of young moringa orchard can be economically beneficial to farmers in the northern region of Bangladesh.
2. The developed model should be replicated in the moringa and other fruit tree based agroforestry production system in Bangladesh.
3. The present study opened the avenues for further study about the ability of moringa leaves to the fertilization of soil.
4. Further research could be carried out at various agroclimatic and soil type of the country to identify suitable production systems of lettuce with organic fertilizer application required for maximum productivity.

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APPENDICES

Appendix-I: The Physical and Chemical Properties of Soil of the Experimental field (Moringa Orchard) of Department of Agroforestry and Environment, HSTU, Dinajpur

Soil Characters	Physical and Chemical Properties
Texture	
Sand (%)	65
Silt (%)	30
Clay (%)	5
Textural Class	Sandy loam
CEC (meq/100g)	8.07
pH	5.35
Organic matter (%)	1.06
Total Nitrogen (%)	0.10
Sodium (meq/100g)	0.06
Calcium (meq/100g)	1.30
Magnesium (meq/100g)	0.40
Potassium (meq/100g)	0.26
Phosphorus (meq/100g)	24.0
Sulphur ($\mu\text{g/g}$)	3.2
Boron ($\mu\text{g/g}$)	0.27
Iron ($\mu\text{g/g}$)	5.30
Zinc ($\mu\text{g/g}$)	0.90

Source: Soil Resource Development Institute, Dinajpur

Appendix II: Factorial ANOVA tables.

1. Factorial AOV Table for Plant Height (cm) at 45 DAS

Source	DF	SS	MS	F	P
TreaT ₁	1	812.239	812.239	301.52	0.0000
TreaT ₂	3	26.466	8.822	3.27	0.0485
TreaT ₁ *TreaT ₂	3	4.048	1.349	0.50	0.6870
Error	16	43.101	2.694		
Total	23	885.854			

Grand Mean 20.283

CV 8.09

2. Factorial AOV Table for Plant Height (cm) at 60 DAS

Source	DF	SS	MS	F	P
TreaT ₁	1	771.460	771.460	289.23	0.0000
TreaT ₂	3	41.476	13.825	5.18	0.0108
TreaT ₁ *TreaT ₂	3	9.015	3.005	1.13	0.3679
Error	16	42.676	2.667		
Total	23	864.628			

Grand Mean 24.722

CV 6.61

3. Factorial AOV Table for Leaves Number at 45 DAS

Source	DF	SS	MS	F	P
TreaT ₁	1	254.802	254.802	78.21	0.0000
TreaT ₂	3	64.048	21.349	6.55	0.0042
TreaT ₁ *TreaT ₂	3	27.348	9.116	2.80	0.0736
Error	16	52.127	3.258		
Total	23	398.325			

Grand Mean 17.075

CV 10.57

4. Factorial AOV Table for Leaves Number at 60 DAS

Source	DF	SS	MS	F	P
TreaT ₁	1	224.482	224.482	59.22	0.0000
TreaT ₂	3	71.810	23.937	6.31	0.0050
TreaT ₁ *TreaT ₂	3	21.348	7.116	1.88	0.1741
Error	16	60.653	3.791		
Total	23	378.293			

Grand Mean 21.067

CV 9.24

5. Factorial AOV Table for Leaves Length at 45 DAS

Source	DF	SS	MS	F	P
TreaT ₁	1	416.000	416.000	174.43	0.0000
TreaT ₂	3	43.467	14.489	6.08	0.0058
TreaT ₁ *TreaT ₂	3	10.029	3.343	1.40	0.2787
Error	16	38.159	2.385		
Total	23	507.654			

Grand Mean 17.232

CV 8.96

6. Factorial AOV Table for Leaves Length at 60 DAS

Source	DF	SS	MS	F	P
TreaT ₁	1	405.410	405.410	169.05	0.0000
TreaT ₂	3	48.519	16.173	6.74	0.0038
TreaT ₁ *TreaT ₂	3	8.739	2.913	1.21	0.3365
Error	16	38.371	2.398		
Total	23	501.039			

Grand Mean 18.011

CV 8.60

7. Factorial AOV Table for Leaves Breadth at 45 DAS

Source	DF	SS	MS	F	P
TreaT ₁	1	66.035	66.0348	82.29	0.0000
TreaT ₂	3	25.399	8.4663	10.55	0.0005
TreaT ₁ *TreaT ₂	3	6.100	2.0332	2.53	0.0936
Error	16	12.839	0.8024		
Total	23	110.372			

Grand Mean 11.923

CV 7.51

8. Factorial AOV Table for Leaves Breadth at 60 DAS

Source	DF	SS	MS	F	P
TreaT ₁	1	81.512	81.5122	83.90	0.0000
TreaT ₂	3	26.568	8.8559	9.12	0.0009
TreaT ₁ *TreaT ₂	3	4.186	1.3952	1.44	0.2693
Error	16	15.545	0.9716		
Total	23	127.810			

Grand Mean 12.566

CV 7.84

9. Factorial AOV Table for Leaves Number per Plant

Source	DF	SS	MS	F	P
TreaT ₁	1	238.770	238.770	70.83	0.0000
TreaT ₂	3	68.691	22.897	6.79	0.0036
TreaT ₁ *TreaT ₂	3	20.485	6.828	2.03	0.1509
Error	16	53.933	3.371		
Total	23	381.880			

Grand Mean 21.054

CV 8.72

10. Factorial AOV Table for Leaves Number per Plot

Source	DF	SS	MS	F	P
TreaT ₁	1	859574	859574	70.83	0.0000
TreaT ₂	3	247288	82429	6.79	0.0036
TreaT ₁ *TreaT ₂	3	73744	24581	2.03	0.1509
Error	16	194160	12135		
Total	23	1374767			

Grand Mean 1263.3

CV 8.72

11. Factorial AOV Table for Leaves Weight per Plant (g)

Source	DF	SS	MS	F	P
TreaT ₁	1	54243	54243.1	48.97	0.0000
TreaT ₂	3	45850	15283.5	13.80	0.0001
TreaT ₁ *TreaT ₂	3	7927	2642.3	2.39	0.1073
Error	16	17722	1107.6		
Total	23	125742			

Grand Mean 156.37

CV 21.28

12. Factorial AOV Table for Leaves Weight per Plot (g)

Source	DF	SS	MS	F	P
TreaT ₁	1	2.310E+08	2.310E+08	90.26	0.0000
TreaT ₂	3	1.821E+08	6.070E+07	23.71	0.0000
TreaT ₁ *TreaT ₂	3	2.007E+07	6690554	2.61	0.0870
Error	16	4.095E+07	2559428		
Total	23	4.741E+08			

Grand Mean 9131.9

CV 17.52

13. Factorial AOV Table for Weight of Lettuce per Plant (kg)

Source	DF	SS	MS	F	P
TreaT ₁	1	0.06202	0.06202	89.66	0.0000
TreaT ₂	3	0.05150	0.01717	24.82	0.0000
TreaT ₁ *TreaT ₂	3	0.00535	0.00178	2.58	0.0898
Error	16	0.01107	0.00069		
Total	23	0.12993			

Grand Mean 0.1517

CV 17.34

14. Factorial AOV Table for Yield of Lettuce per Plot (kg)

Source	DF	SS	MS	F	P
TreaT ₁	1	231.012	231.012	90.16	0.0000
TreaT ₂	3	182.091	60.697	23.69	0.0000
TreaT ₁ *TreaT ₂	3	20.063	6.688	2.61	0.0873
Error	16	40.998	2.562		
Total	23	474.164			

Grand Mean 9.1317

CV 17.53

15. Factorial AOV Table for Yield of Lettuce per Plot (ton)

Source	DF	SS	MS	F	P
TreaT ₁	1	641.70	641.700	90.18	0.0000
TreaT ₂	3	505.85	168.616	23.70	0.0000
TreaT ₁ *TreaT ₂	3	55.74	18.581	2.61	0.0872
Error	16	113.85	7.116		
Total	23	1317.14			

Grand Mean 15.219

CV 17.53

16. Factorial AOV Table for Dry Weight (g)

Source	DF	SS	MS	F	P
TreaT ₁	1	11.0840	11.0840	9.51	0.0071
TreaT ₂	3	7.7576	2.5859	2.22	0.1255
TreaT ₁ *TreaT ₂	3	3.1807	1.0602	0.91	0.4582
Error	16	18.6467	1.1654		
Total	23	40.6691			

Grand Mean 9.9912

CV 10.80

17. Factorial AOV Table for Moisture (%)

Source	DF	SS	MS	F	P
TreaT ₁	1	19.620	19.6204	1.43	0.2497
TreaT ₂	3	5.270	1.7566	0.13	0.9423
TreaT ₁ *TreaT ₂	3	16.444	5.4814	0.40	0.7558
Error	16	220.017	13.7511		
Total	23	261.352			

Grand Mean 87.031

CV 4.26

18. Factorial AOV Table for Dry matter (%)

Source	DF	SS	MS	F	P
TreaT ₁	1	29.7038	29.7038	28.76	0.0001
TreaT ₂	3	10.7797	3.5932	3.48	0.0408
TreaT ₁ *TreaT ₂	3	23.9942	7.9981	7.74	0.0020
Error	16	16.5236	1.0327		
Total	23	81.0013			

Grand Mean 12.927

CV 7.86

19. Factorial AOV Table for Protein (%)

Source	DF	SS	MS	F	P
TreaT ₁	1	0.3243	0.32434	0.89	0.3599
TreaT ₂	3	0.3199	0.10664	0.29	0.8305
TreaT ₁ *TreaT ₂	3	7.4209	2.47364	6.78	0.0037
Error	16	5.8410	0.36506		
Total	23	13.9062			

Grand Mean 2.2838

CV 26.46

20. Factorial AOV Table for Ash (%)

Source	DF	SS	MS	F	P
TreaT ₁	1	1.5453	1.54534	95.83	0.0000
TreaT ₂	3	9.2350	3.07834	190.90	0.0000
TreaT ₁ *TreaT ₂	3	2.4385	0.81284	50.41	0.0000
Error	16	0.2580	0.01612		
Total	23	13.4769			

Grand Mean 1.6313

CV 7.78

21. Factorial AOV Table for Chlorophyll a mg g⁻¹

Source	DF	SS	MS	F	P
TreaT ₁	1	0.09004	0.09004	0.59	0.4537
TreaT ₂	3	0.99491	0.33164	2.17	0.1312
TreaT ₁ *TreaT ₂	3	3.30191	1.10064	7.21	0.0028
Error	16	2.44300	0.15269		
Total	23	6.82986			

Grand Mean 5.1613

CV 7.57

22. Factorial AOV Table for Chlorophyll b mg g⁻¹

Source	DF	SS	MS	F	P
TreaT ₁	1	0.49882	0.49882	6.21	0.0240
TreaT ₂	3	0.17695	0.05898	0.73	0.5464
TreaT ₁ *TreaT ₂	3	0.07635	0.02545	0.32	0.8129
Error	16	1.28447	0.08028		
Total	23	2.03658			

Grand Mean 2.0792

CV 13.63

23. Factorial AOV Table for Carotene mg g⁻¹

Source	DF	SS	MS	F	P
TreaT ₁	1	0.14570	0.14570	1.58	0.2262
TreaT ₂	3	1.48501	0.49500	5.38	0.0094
TreaT ₁ *TreaT ₂	3	0.27571	0.09190	1.00	0.4185
Error	16	1.47127	0.09195		
Total	23	3.37770			

Grand Mean 1.5571

CV 19.47

24. Factorial AOV Table for Ca mg 100g⁻¹

Source	DF	SS	MS	F	P
TreaT ₁	1	20791	20790.5	79.25	0.0000
TreaT ₂	3	66020	22006.7	83.89	0.0000
TreaT ₁ *TreaT ₂	3	43495	14498.3	55.27	0.0000
Error	16	4197	262.3		
Total	23	134503			

Grand Mean 547.76

CV 2.96

25. Factorial AOV Table for Mg mg 100g⁻¹

Source	DF	SS	MS	F	P
TreaT ₁	1	3433.7	3433.7	115.20	0.0000
TreaT ₂	3	18081.2	6027.1	202.20	0.0000
TreaT ₁ *TreaT ₂	3	60456.8	20152.3	676.08	0.0000
Error	16	476.9	29.8		
Total	23	82448.6			

Grand Mean 277.96

CV 1.96

26. Factorial AOV Table for Na mg 100g⁻¹

Source	DF	SS	MS	F	P
TreaT ₁	1	573.21	573.206	41.17	0.0000
TreaT ₂	3	1891.73	630.576	45.29	0.0000
TreaT ₁ *TreaT ₂	3	502.65	167.549	12.03	0.0002
Error	16	222.76	13.923		
Total	23	3190.34			

Grand Mean 97.530

CV 3.83

27. Factorial AOV Table for K mg 100g⁻¹

Source	DF	SS	MS	F	P
TreaT ₁	1	18737.1	18737.1	167.14	0.0000
TreaT ₂	3	56678.5	18892.8	168.53	0.0000
TreaT ₁ *TreaT ₂	3	8522.7	2840.9	25.34	0.0000
Error	16	1793.7	112.1		
Total	23	85732.0			

Grand Mean 220.55

CV 4.80

28. Factorial AOV Table for S mg 100g⁻¹

Source	DF	SS	MS	F	P
TreaT ₁	1	8.093E+09	8.093E+09	1.00	0.3321
TreaT ₂	3	2.426E+10	8.085E+09	1.00	0.4185
TreaT ₁ *TreaT ₂	3	2.424E+10	8.081E+09	1.00	0.4188
Error	16	1.294E+11	8.091E+09		
Total	23	1.860E+11			

Grand Mean 18833

CV 477.61

29. Factorial AOV Table for P mg 100g⁻¹

Source	DF	SS	MS	F	P
TreaT ₁	1	214.32	214.323	64.99	0.0000
TreaT ₂	3	357.14	119.046	36.10	0.0000
TreaT ₁ *TreaT ₂	3	614.07	204.691	62.07	0.0000
Error	16	52.76	3.298		
Total	23	1238.30			

Grand Mean 30.347

CV 5.98

30. Factorial AOV Table for Temperature in (°c)

Source	DF	SS	MS	F	P
TreaT ₁	1	90.987	90.9872	29.34	0.0001
TreaT ₂	3	6.336	2.1121	0.68	0.5763
TreaT ₁ *TreaT ₂	3	3.737	1.2457	0.40	0.7537
Error	16	49.611	3.1007		
Total	23	150.672			

Grand Mean 34.872

CV 5.05

31. Factorial AOV Table for Temperature out (°c)

Source	DF	SS	MS	F	P
TreaT ₁	1	0.3037	0.30375	0.14	0.7136
TreaT ₂	3	4.1146	1.37153	0.63	0.6059
TreaT ₁ *TreaT ₂	3	5.9746	1.99153	0.92	0.4556
Error	16	34.8067	2.17542		
Total	23	45.1996			

Grand Mean 28.979

CV 5.09

32. Factorial AOV Table for Relative Humidity (%)

Source	DF	SS	MS	F	P
TreaT ₁	1	104.167	104.167	24.75	0.0001
TreaT ₂	3	4.333	1.444	0.34	0.7944
TreaT ₁ *TreaT ₂	3	3.500	1.167	0.28	0.8410
Error	16	67.333	4.208		
Total	23	179.333			

Grand Mean 35.167

CV 5.83

Appendix III: Production cost analysis of Lettuce cultivation under different agroforestry production systems.

Treatment	Non-material cost (TK/ha)			Material Cost (TK/ha)						T. Input Cost	Overhead Cost			Total cost of production (TK/ha)
	Moringa	Lettuce	T. N.M Cost	Seed	Fertilizer	Pesticide	Irrigation	Initial Plantation Cost	T. M. Cost		Interest Input cost @ 8% for the Plant season (tk/ha)	Interest of the value of the Land (tk. 300000/ha) @ 8% for the Plant season	Miscellaneous Cost @ 5% of the total input cost (tk/ha)	
S ₁ F ₁	12500	14000	26500	21000	18500	8000	5500	9300	62300	88800	7104	24000	4440	124344
S ₁ F ₂	12500	14000	26500	21000	7500	8000	5500	9300	51300	77800	6224	24000	3890	111914
S ₁ F ₃	12500	14000	26500	21000	3000	8000	5500	9300	46800	73300	5864	24000	3665	106829
S ₁ F ₄	12500	8000	20500	21000	0	8000	5500	9300	43800	64300	5144	24000	3215	96659
S ₂ F ₁	12500	14000	26500	22500	18500	8000	5500	9300	63800	90300	7224	24000	4515	126039
S ₂ F ₂	12500	14000	26500	22500	7500	8000	5500	9300	52800	79300	6344	24000	3965	113609
S ₂ F ₃	12500	14000	26500	22500	3000	8000	5500	9300	48300	74800	5984	24000	3740	108524
S ₂ F ₄	12500	8000	20500	22500	0	8000	5500	9300	45300	65800	5264	24000	3290	98354

Note: The number of moringa stem was 625/ha, price of each moringa stem was 5 tk. Plantation cost of moringa stem was 15tk Plant⁻¹. Rotation year of moringa 20 years. Cow dung 750tk/ton, urea 18tk/kg, TSP29tk/kg, MP 17tk/kg, Gypsum 11tk/kg, ZnSO₄ 133 tk/kg Labor cost 400tk/day.

Where,

S₁F₁ =(Lettuce sole + Chemical fertilizer), S₁F₂ =(Lettuce sole + Cow dung), S₁F₃ =(Lettuce sole + Poultry manure), S₁F₄ =(Lettuce sole + No fertilizer), S₂F₁ =(Lettuce with Moringa + Chemical fertilizer), S₂F₂ =(Lettuce with Moringa + Cow dung), S₂F₃ =(Lettuce with Moringa + Poultry manure), S₂F₄ =(Lettuce with Moringa +No fertilizer)

Appendix-IV: Some Plates of the Experiment



Plate-1: Seeds of the lettuce for different production systems.



Plate-2: Land preparation and sowing of lettuce seeds according to experimental layout.



Plate-3: Instruction from supervisor how to measure parameters and light intensity.



Plate-4: Collection of data for vegetative growth stages.



Plate-5: Vegetative growth stages of lettuce Plants at 45 DAS nad 60 DAS.



Plate-6: Field visit of the supervisor and his advice about harvesting symptoms of lettuce.



Plate-8: Collection of yield data after harvest.



Plate-9: Processing to measure dry matter (%) and ash content (%).