EFFECT OF MORINGA LEAF EXTRACT ON GROWTH AND YIELD OF TOMATO (*Solanum lycopersicum* L.)

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CERTIFICATE

This is to certify that the thesis entitled, ***"EFFECT OF MORINGA LEAF EXTRACT ON GROWTH AND YIELD OF TOMATO (Solanum lycopersicum L.)" was*** *submitted to the faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the degree of* ***MASTER OF SCIENCE AGROFORESTRY AND ENVIRONMENTAL SCIENCE*** *embodies the result of a piece of bona fide research work carried out by* ***MD. SHARIFUL ISLAM,*** *Registration No. 19-10305 under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma in any other institutes.*

I further certify that any help or sources of information, as have been availed during this investigation have duly been acknowledged.

Dated: December, 2021
Place: Dhaka, Bangladesh

Md. Golam Jilani Helal
Assistant Professor
Supervisor

DEDICATED TO MY
BELOVED PARENTS
AND TEACHERS WHO LAID
THE FOUNDATION OF MY
SUCCES

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ABSTRACT

The experiment was carried out at Agroforestry Field Laboratory, Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from January 2021 to April 2021 to find out "Effect of Moringa leaf extract on growth and yield of Tomato (*Solanum lycopersicum* L.)". The pot experiment consisted of six treatments *viz*., T_0, T_1, T_2, T_3, T_4, and T_5 (control, 10 ml, 20ml, 30 ml, 40 ml, and 50 ml concentrations of Moringa leaf extract respectively). This experiment was laid out in Randomized Complete Block Design (RCBD) with four replications. In the case of growth parameters, the highest plant height (62.00 cm) and the number of leaf plant^{-1} (52) were observed in T_5 whereas the lowest result was observed from T_0 treatment with plant height (38.50 cm) and the number of leaf plant^{-1} (27). In terms of yield contributing parameters with Moringa leaf extract, T_5 showed the lowest days (39 days) to 1st flowering whereas the highest days to 1st flowering were achieved from T_0 treatment at 50 days. The highest fruit number plant^{-1} (24), individual fruit weight (65 g), and fruit yield ha^{-1} (70.2 t) was found in the treatment T_5 while the lowest number of fruits per plant (8), individual fruit weight (44.78 g), fruit yield ha^{-1} (31.5 t) was obtained from T_0 treatment. Different concentrations of Moringa leaf extract with Tomato plant had a strong positive relation with around all parameters. To base on observed data points, predicted that 50 ml concentrations of Moringa leaf extract will supply the optimum Tomato yield ha^{-1}(70.2 t). This study indicates that the Moringa leaf extract used significantly increased the growth and yield of tomato plants in all the trials with fresh leaves, regular branching, healthy fruits, and regular flowering.

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LIST OF ABBREVIATIONS AND ACRONYMS

Full Word	Abbreviation	Full Word	Abbreviation
Agro-Ecological Zone	AEZ	Etcetera	etc.
Bangladesh Bureau of Statistics	BBS	Food and Agriculture Organization	FAO
Bangladesh Council of Scientific Research Institute	SCSRI	Id est (L), that is	i.e.
Centimeter	Cm	Kilogram (s)	Kg
Percent Coefficient of Variation	CV%	Least Significant Difference	LSD
Days After Transplanting	DAT	Mili Litre	ml
Duncan's Multiple Range Test	DMRT	Master of Science	M.S.
%	Percentage	Serial Number	SL. No.
Exempli gratia (L), for example	e.g.	Sher-e-Bangla Agricultural University	SAU
Moringa Leaf Extract	MLF	World Health Organization	WHO
Standard Error	SE	Treatment	T
Variety	Var.	And others	et al.

CHAPTER 1

INTRODUCTION

Modern agricultural production aims to provide sustainable management practices that are eco-friendly and low-cost. In recent years, the natural plant growth enhancer is the main focus of study for many researchers around the globe. *Moringa oleifera* L. leaves are used as green manure and as a potential natural growth stimulant (Fuglie, 2000). The extract prepared from fresh moringa leaf is a unique source of vitamins, hormones, antioxidants, osmoprotectants, carotenoids, polyphenols, phenolic acids, flavonoids, alkaloids, glucosinolates, isothiocyanates, tannins, saponins and secondary metabolites (Gopalakrishnan et al., 2016). The presence of a significant quantity of phytohormones such as cytokinin, gibberellin, indole-3-acetic acid, zeatin, mineral nutrient elements, vitamins such as ascorbic acid, carotenoid, anti-oxidants such as flavonoid and phytochemicals like phenolic and glucosinolates and isothiocyanates, osmoprotectants in Moringa leaf extract has made it an effective plant bio-stimulant (Leone *et al*., 2015). When Moringa leaf extract is exogenously applied to plants, it has the potential to act as a growth promoter to increase the production of many vegetable and field crops (Ozobia, 2014). The foliar use of Moringa leaf extract can contribute to improving physiological and biochemical tributes of plants such as photosynthetic and enzymatic activities, which appropriate the efficiency of utilizing nutrients leading to enhanced plant growth and productivity. Many recent research findings have suggested the use of Moringa leaf extractas a biostimulant to accelerate vegetative and reproductive growth, antioxidant defense, and yield under normal and stressed conditions (Aluko et al., 2017). Bangladesh is an agrarian country where agriculture is the mainstay of the country's economy contributing largely to the Gross Domestic Product (GDP) and serving as the greatest employment sector for its people (BBS, 2018). Vegetables are considered an important source of vitamins and minerals (Ulger *et al*., 2018). Thus, a balanced intake of cereals and vegetables is extremely important for the daily dietary requirement of the increasing population. Vegetable production in Bangladesh is currently inadequate to fulfill the nutritional demand of the people due to the limited production system. Bangladesh is facing a great challenge in agricultural food production for its ever-rising population with the shrinkage of agricultural lands (BBS, 2018). Our land quality is deteriorating day by day due to the degradation of soil fertility, nutrient mining, depletion of organic matter, soil and water pollution, soil salinity, acidity, and long-term water logging problems. Traditional agricultural practices often threaten soil and human health, degrade the agricultural environment, and destroy agricultural biodiversity. For the improvement of soil health and crop productivity, this is essential to develop an eco-friendly sustainable approach to increasing agricultural productivity in the context of Bangladesh. The modern agricultural system should give attention to conserving agricultural biodiversity and should adopt sustainable techniques. Application of Moringa leaf extract on foliage as a bio-stimulant is an established readily available sustainable approach for increasing yields of crops with minimum input cost (Zulfiqar *et a*l.,2020). Furthermore, moringa leaves can be used in feed production, medicinal purposes, seed multiplication, and eco-friendly pesticides for their high nutritional value (Meireles *et al*., 2020). The beneficial effects of moringa leaves should be incorporated into modern farming practices for sustainable plant growth and priority should be given to research related to moringa to highlight its roles in agriculture for the welfare of the smallholder farmers. Still, now, there are a few reports that illustrate the effects of Moringa leaf extract on field and vegetable crops at a time. The performance of Moringa leaf extract in different crops should be judged to find out its suitability in a large-scale application. Therefore, the experiment was conducted to assess the effectiveness of the foliar application of Moringa leaf extract to enhance plant growth, yield, and nutrient uptake of tomatoes for developing a sustainable agricultural production system.

Vegetables are important crops for an additional supply of human nutritional requirements. (Tenu and Emu, 2005) described vegetables, which include tomatoes as high-value crops which have high nutritive value. In particular, they are high in vitamins, minerals, and fiber. But according to reports (Stock, 2004) the Indian subcontinent countries were designated by FAO as having a short supply of these crops. One of the constraints to the sustained production of tomatoes in this region is the lack of hormonal application. This leads to poor plant growth and increased disease pressure which results in a decline in agricultural food production. Plant hormones can be used to increase yield per unit area because they influence every phase of plant growth and development. Traditionally, there are five groups of growth regulators are listed: auxins, gibberellins, abscisic acid, ethylene, and cytokinins (Prosecus, 2006). Cytokinins enhance food production. Zeatin is one form of the most common forms of naturally occurring cytokinin in plants. Fresh *Moringa oleifera* leaves have been shown to have high zeatin content. Moringa leaves gathered from various parts of the world were found to have high zeatin concentrations of between 5 ml and 200 ml/g of leaves. Moringa leaf extract was sprayed onto leaves of onions, bell pepper, soya beans, sorghum, coffee, tea, chili, melon, and maize and was shown to increase the yields of these crops (Fuglie, 2000). If moringa extract can increase yields, then the potential benefit to the smallholder farmers in Bangladesh would be great. The effect of moringa extract on other crops is unknown. The objective of the current study is to test the effect of moringa extract on the growth and development of tomatoes. The hypothesis of this research was the application of moringa extract on tomato (*Lycopersicon esculentum* L. *var. Rodade*) can increase the growth and yield of the crop. Therefore, the present study was undertaken with the following objectives:

i) To evaluate the effect of *Moringa oleifera* leaf extract as a growth hormone on the growth and yield performance of tomato.

ii) To find out the optimum dose of moringa leaf extract for Tomato production.

CHAPTER 2

REVIEW OF LITERATURE

This study was conducted to evaluate the efficacy of Moringa leaf extract on early growth and tomato yield effects. There is very little literature on these topics, both domestically and overseas. However, literature relating to tomato growth and yield using a moringa leaf extract, in a tree-crop agroforestry system, characteristics of tree species, and the significance of the agroforestry system were gathered through reviewing journals, theses, internet browsing, reports, newspapers, and other forms of publications and are presented in this Chapter in the following sections.

2.1 Concept of agroforestry and its importance

According to the ICRAF's current definition, woody perennials are collectively referred to as land-use systems and practices that intentionally coexist with crops and/or animals on the same land-management unit. The integration may take place in a temporal or spatial mixture. Agroforestry typically involves interactions between the woody and non-woody parts on both an ecological and financial level. This definition has helped establish agroforestry as a distinct field of agricultural research (Sanchez, 1995).

According to Nair (1989), agroforestry is a system of land use that involves the simultaneous or sequential integration of trees with agricultural crops and/or animals in a socially and environmentally acceptable way to increase the total productivity of plants and animals sustainably from a unit of farmland, particularly in situations with low levels of technology inputs and marginal lands.

Agroforestry is used in home gardens, farmlands, forests, and more (Millat-e-Mustafa, 1997). However, the sustainability of these methods is a significant issue in Bangladesh. Agroforestry is thought to be an effective and sustainable land use choice, especially for people with limited means (Stocking *et al*., 1990).

According to Abedin *et al*. (1990), agroforestry is regarded as one of the methods for increasing tree production in countries like Bangladesh where there is minimal opportunity for the development of pure forests due to the clear preference for the production of food crops.

According to Lawrence and Hardostry (1992), the landowners cited land-use diversity as one of the potential benefits of practicing agroforestry, along with increased productivity, aesthetic appeal, and income diversity. The most common potential barriers to practicing agroforestry were a lack of knowledge (28 percent), a lack of technical support (18 percent), the expense of setting up the practice (14 percent), and the fact that it is not a well-established practice. Additionally, they discovered that there was a lot of potential for agroforestry to be used across the state, and non-industrial private forestland owners were chosen for further research into this possibility.

According to Basavaraju and Gururaja (2000), choosing the right tree species for agroforestry is crucial. Due to varying production and protection objectives, it is not always possible to choose tree species with all the required traits for agroforestry. According to the article, in these situations, agroforestry systems must be maintained by planting trees at the ideal tree density, arranging them properly, and trimming and thinning their crowns and roots to lessen their adverse effects.

According to Neupane and Thapa (2001), maintaining agricultural production in the Nepalese highlands depends on adopting measures that reduce the pace of soil degradation, boost crop yields, and enhance farm revenue. Additionally, they said that by making good contributions to household income, agroforestry has a great deal of potential to improve food production and farmers' economic conditions sustainably.

2.2 Moringa plant

The semi-arid, tropical, and subtropical regions are where the "Moringa" tree is most commonly planted. It is indigenous to the sub-Himalayan regions of Afghanistan, Bangladesh, Pakistan, and India (Fahey, 2005). Although it tolerates poor soil, especially in coastal locations, it thrives best in dry, sandy soil. It is a drought-resistant tree that grows quickly. Africa, Central and South America, Sri Lanka, India, Mexico, Malaysia, Indonesia, and the Philippines are currently among the countries that farm it extensively. The moringa is a small, slender, deciduous, perennial tree that grows to a height of about 10 meters. It has drooping branches, brittle stems and branches, corky bark, feathery pale green 30-60 cm long compound leaves, with many small leaflets that are 1.3-2 cm long and 0.6-0.3 cm wide, fragrant white or creamy-white flowers that are 2.5 cm in diameter, and borne in sprays. Almost every part of the Moringa tree can be utilized as food or has some other beneficial quality, making it one of the most useful trees in the world. It is utilized as animal feed in the tropics, and moringa micronutrient liquid, a natural anthelmintic (kills parasites) and adjuvant (to aid or enhance another treatment), is used in many nations as a metabolic conditioner to help against endemic diseases in underdeveloped countries (Foidle *et al*., 2001).

The most nutrient-dense plant to date has been identified as *Moringa oleifera*. For nutrition and healing, moringa offers a potent and uncommon combination of minerals, amino acids, antioxidants, anti-aging, and anti-inflammatory qualities. The miracle tree Moringa is a rich local supply of highly digestible proteins, calcium, iron, and vitamin C. (Fahey, 2005). According to some articles and studies, the dry leaves of Moringa contain 7 times as much vitamin C as an orange, 10 times vitamin A as a carrot, 17 times as much calcium as milk, 15 times as much potassium as bananas, 25 times as much iron as spinach, and 9 times as much protein as yogurt (Fuglie, 1999). Aside from that, it also includes vitamin B complex, chromium, copper, magnesium, manganese, phosphorus, and zinc (Fuglie, 2000).

2.3 The Importance of Moringa Leaf Extract

Crop production was boosted by 20–35% by a spray prepared from moringa leaves to promote plant growth. Spray impacts crops by giving them a longer lifespan, heavier roots, stems, and leaves, as well as larger and more plentiful fruit and a 20–35% increase in output (Foidle *et al*., 2001), emphasizing the possibility of using it as a foliar spray to quicken the growth of immature plants. In numerous trials, MLE demonstrated to be the optimum plant growth stimulant (Makkar and Becker 1996; Nouman *et al*., 2011). According to Makkar *et al*. (2007), moringa leaves are a good source of antioxidants, carotene, vitamin C, and plant development factors.

Siddhuraju and Becker (2003), investigation into the antioxidant abilities of moringa leaf extract revealed that it: (1) decreased potassium ferricyanide; (2) scavenged superoxide radicals; (3) prevented the peroxidation of lipid membrane in liposomes; and (4) could donate hydrogen and scavenge radicals.

Both methanolic and aqueous extracts of Chinese medicinal herbs showed antioxidant properties that were positively correlated with total phenolic contents, according to (Cai *et al*., 2004). When compared to extracts from other parts of the plant, such as the stem and fruits, the aqueous extract from Andrographis paniculata leaves displayed higher phenolic content and antioxidant potential (Arash *et al*., 2010). In the form of zeatin, antioxidant proteins, ascorbates, and phenols, (Makkar *et al*., 2007) discovered that MLE includes substantial amounts of calcium, potassium, and cytokinin. Rangeland grass *Echinochloa crusgalli* responded favorably to MLE priming, exhibiting a marked increase in shoot vigor, increased leaf production, and fertile tillers (Nouman *et al*., 2012).

However, scientists proposed exogenous application of suitable solutes, antioxidant chemicals, mineral nutrients, and plant growth regulators as a shotgun method based on physiological and biochemical grounds of stress tolerance in crops. The utilization of plant extracts containing a significant number of suitable osmolytes, antioxidants, and plant growth regulators could be a financially sound strategy because synthetic versions of these substances are expensive. Moringa oleifera has drawn a lot of interest among naturally occurring plant growth promoters due to its leaves' presence of cytokinin, antioxidants, and macro and micronutrients.

The nutritional and therapeutic characteristics of the versatile vegetable tree known as moringa are initially thought to be its most intriguing uses. There are 13 species in the genus Moringa, which is part of the family Moringaceae. Moringa is the most widely farmed species and is also known as the "horseradish tree" or "drumstick tree" because its roots can be substituted for horseradish. Native to the sub-Himalayan regions of north western India, Pakistan, Bangladesh, and Afghanistan, Moringa (Foidl *et al*., 2001). High biomass yield and resilience to severe environmental circumstances are features of this versatile tree (Foidl *et al*., 2001).

The tree is between five and ten meters tall (Morton, 1991). It is common near the sand bottoms of rivers and streams and is both wild and farmed throughout the plains, notably in hedges and home yards. It does best in a tropical insular climate (Qaiser, 1973). If planted during the rainy season, moringa trees don't require much water to germinate and thrive. They can even flourish without irrigation. Within twenty days, the roots will form, enabling young plants to withstand drought (Saint Sauveur and Broin, 2010).

Numerous studies and developments have been done on the moringa tree because of its various potential uses. With the least amount of growing and harvesting effort, it delivers a variety of foods and other profitable applications. The tree can also be utilized to spruce up streets and slum areas and stop deforestation. In many nations, especially in India, Pakistan, the Philippines, Hawaii, and many areas of Africa, the leaves, fruit, blossoms, and immature pods are consumed as highly nutritious vegetables (Anwar, 2005).

Beta-carotene, protein, vitamin C, calcium, potassium, and iron are all found in greater quantities in moringa leaves than in carrots, peas, milk, or bananas. It has been demonstrated that M. oleifera seed powder works well as a natural coagulant to treat river streams with a disproportionately high level of suspended particles (Fuglie, 2001). The leaves of the moringa species intercept less light than those of other agroforestry plants and respond well to pruning (Immanuel and Ganapathy, 2010). Therefore, consistent pruning and leaf harvesting would probably result in enough light beneath the canopy to permit intercropping. Due to its rapid growth, Moringa was shown to be competitive with several herbaceous plants, according to Palada *et al.* (2008). However, during the early establishing phase, lemon grass (*Cymbopogon citratus*) and basil (*Ocimum basilicum*) may coexist with Moringa.

According to information obtained from the Bangladesh Bureau of Statistics (BBS, 2014), M. oleifera is primarily grown in gardens and homesteads. An estimated 10 tons of Moringa pods are gathered annually from commercially grown trees, and an additional 2860 metric tons are harvested from domestic gardens. The total area of moringa planted in backyard gardens is not estimated by the Bangladesh Bureau of Statistics (BBS). The BBS statistics support the key conclusions of the farmer survey. Southern Bangladesh rarely sees M. oleifera commercial cultivation.
Moringa is not at all grown on agricultural fields in the Barisal and Patuakhali Regions. In Jessore compared to Khulna, the average harvest per tree is higher. The information is not, however, complete or conclusive; for instance, there were no data available for the estimated area under cultivation in Jessore, nor were there any data available for homestead gardening (BBS, 2014).

2.4 Response of crops in the agroforestry System

Different crops responded differently in agroforestry systems. When grown in shade, several vegetables like tomatoes, brinjal, and coriander developed larger leaves (Miah, 2001). The variability of 95 relationships between *Abelmuscus esculentus* and *Abelmuscus tetraphylous* was examined by Martin and Rhodes in 1983. All of the studied characters, including plant height, plant spread, number of primary bracbranchesys until flowering, nodes where the first flower appeared, number of leaves per plant, leaf size, petiole length, number of pods per plant, pod weight, and total yield, were associated with significant differences. The yield of seeds rises with plant density. High-density plants were seen to be taller, sparsely branched, less trimmed to lodge e, and producing fewer seeds and pods. It was shown that the shadowing effect reduced maize production. While moisture competition was the primary element generating a severely poor yield in the second season, which was shorter and had a quick end to the rain (Sing *et al*., 1989).

According to Agrawal et al. (1992), the rice that was added produced a solitary yield of mungbean that ranged from 59% to 999%. Additionally, they noted that intercropping short-duration grain legumes with upland rice had demonstrated potential productivity and effective resource management. In a field experiment conducted in Hisar, Haryana, during the rainy season of 1992-1993, Singh Prasad (1989) noted that 7 soybean cultivars were cultivated at a density of 200000, 400000, or 600000 plants/ha. Interactions between cultivar, plant density, and year were obvious.

Gondane and Bhatia (1995), investigated the variability of 50 Okra genotypes. They noticed that every genotype reacted to the environment differently. Plant height, plant spread, number of nodes per plant, number of leaves per plant, leaf length, leaf breadth, petiole length, pod per plant, nodes to first t pod, and yield were among the yield components that varied significantly.

The artificial shade net was positioned 2 meters above the pots to impose the three levels of irradiance for eight days. At the beginning and peak of flowering, increasing shade increased stomatal conductance, intercellular carbon concentrations, and decreased midday photosynthetic rates. According to Reddy et al. (2002), plants grow taller in shaded conditions, and their root length, dry weight, girt h, and total chlorophyll content are all higher, but their yield is lower.

Total plants in 77 percent shade expanded their fruits' leaf whorls at a rate that was slowest at 5-6 MAP and fastest in plants with less shade, which had more leaves, higher leaf areas, and inter-whole shoot lengths. Specific leaf area increased while leaf area ratio and relative growth rate decreased in plants with more shade. In sub-Saharan Africa, it has been demonstrated that fertilizer trees, such as gliricidia (Gliricidia sepium), intercropped or in improved fallows, increase maize (Zea mays) yield over current farmer practice though with varying performance across soil types, climates, and fertilizer application (Sileshi *et al.,* 2010).

2.5 General uses of Moringa leaf extract

To increase drought tolerances, germination, and early seedling development against saline stress in a variety of plants, including maize (Biswas *et al*., 2016), wheat (Yasmeen *et al*., 2013), different cereals-maize, rice, sorghum, and wheat (Phiri, 2010), beans, and other legumes, moringa leaf extract has been treated in the form of a foliar spray (Rady and Mohamed, 2015).

According to (Chang *et al*., 2007), plants sprayed with moringa leaf extract develop more vigorously and improve vegetables' resistance to various environmental stresses. All of the outcomes demonstrate that the treated crops benefited from the use of moringa leaf extracts. Research on the impact of moringa leaf extracts on vegetables is, however, fairly scant. It primarily serves as a growth regulator, environmentally friendly biopesticide, and mineral supplement in vegetable production (Abd El-Hack *et al*., 2018). According to (Culver *et al*., 2012), tomato yield, plant weight, and dry matter were all boosted by the use of moringa leaf extract. Spraying 5% concentrations of moringa leaf extract on pepper plants can enhance growth and production (Matthew, 2016).

(El-Saady and Omar, 2017) claimed in their experiment that the interaction of introducing microorganisms at a rate of 5 cm3/l and spraying MLE over the leaves three or twice produced the best results for head lettuce (cv. Big Bell). In the foliar spray, the physical qualities of rocket (*Eruca vesicaria subsp. sativa*) and some of its medicinal substances are improved (Abdalla, 2013). In pea plants (*Pisum sativum L.*) sprayed with 4% of moringa leaf extract, the significantly highest protein content and fresh pod (82.5% and 45%, respectively) were attained (Merwad, 2018).

The results of every experiment show that moringa leaf extracts boost plant growth and productivity. These crops-onions, bell pepper, soybeans, sorghum, coffee, tea, melon, and maize-all claimed to have this impact (Fuglie, 2000). According to (Hacisevki, 2009), moringa leaf extract also boosted a plant's tolerance to pests and diseases, resulting in bigger fruits and a 20-35% higher yield. In the experiment with spraying 3% MLE, it also lessens the effects of drought stress on squash plants (El-Mageed *et al*., 2017).

As an alternative to inorganic fertilizer, moringa can increase yield while also promoting the germination of seeds, primarily those for field crops (Phiri, 2010). The plants treated with 80 g/L of moringa leaf powder produced sweet peppers with significantly better physical and qualitative characteristics (Sowley *et al*., 2014). In addition, the juice has an antifungal property that is utilized as an appropriate agent for treating seeds rather than chemicals to prevent the attack of fungal infections that are born in seeds (Akinbode and Ikotun, 2008).

The most nutrient-rich plant yet has been identified as *Moringa oleifera*. Since the 1970s, there has been a substantial amount of nutritional research done on this unassuming plant, which has been advancing in less advanced societies for thousands of years. For nutrition and healing, moringa offers a potent and uncommon combination of minerals, amino acids, antioxidants, antiaging, and anti-inflammatory effects. "Mother's Best Friend" and "Miracle Tree" are additional names for the moringa tree.

To combat hunger, the World Health Organization has promoted moringa as a substitute for imported foods since 1998. (UNWFP, 2004; Manzoor *et al*., 2007; Sreelatha and Padma, 2009). Since ancient times, moringa has been used for both nutritional and therapeutic purposes. These include calcium, which helps build strong bones and teeth and prevents osteoporosis; potassium, which is necessary for the proper functioning of the brain and nerves; and proteins, which are the fundamental building blocks of all of our body cells. Vitamin C fights a variety of illnesses including colds and the flu. Vitamin A protects against eye disease, skin disease, heart ailments, diarrhea, and many other diseases. The fact that all of the essential amino acids, which are the building blocks of proteins, are present in moringa leaves is another crucial factor.

Vegetables that contain all of these amino acids are quite uncommon. These amino acids are present in sufficient quantities in moringa, making them beneficial to human bodies. For those who do not eat meat for protein, these leaves may be a big help. Argentine and histidine, two amino acids that are particularly crucial for newborns, are even found in moringa. For babies, whose bodies are unable to produce enough protein to meet their needs for growth, arginine and histidine are particularly crucial. Moringa has the potential to be a very useful food source (Fuglie, 1999; Babu, 2000; Fuglie, 2000; Lockett and Calvert, 2000; fuglie and Lowell, 2001).

Given its nutritional benefits, it can be used to fortify milk, bread, spices, quick noodles, sauces, juices, and other foods. Numerous commercial goods, including tea, neutraceuticals, and Zija soft drinks, are offered everywhere in the world. Gram for gram, a comparison of fresh Moringa leaves to different foods reveals that Moringa is superior. But the micronutrient content of dried leaves is much higher; it is ten times that of carrots in vitamin A, seventeen times that of milk in calcium, fifteen times that of bananas in potassium, twenty-five times that of spinach in iron, and nine times that of yogurt in protein. However, it is only half as much vitamin C as oranges (Manzoor *et al*., 2007).

Inhibiting and scavenging free radicals is a critical function of antioxidants, which protect against infections and degenerative disorders. According to the information found, *Moringa oleifera* extracts from both mature and tender leaves show strong antioxidant activity against free radicals, protect important biomolecules from oxidative damage, and provide significant protection against oxidative damage (Sreelatha and Padma, 2009).

2.6 Effect of moringa leaf extract on growth and yield of other crops

Exogenous application of Moringa leaves extract affects the development, flowering, and vase life of snapdragon cultivars, according to a field experiment conducted by (Jan et al. in 2022). The experiment was set up using a Randomized Complete Block Design with a factorial arrangement consisting of two factors: the concentrations of the Moringa leaf extract (MLE) (0%, 10%, 20%, and 30%) and the cultivars (Potomac and Rocket). The examined parameters were strongly influenced by cultivars and MLE concentrations. According to a statistical study the, Rocket cultivar in terms of plant-1 leaves (126.50), stem diameter (11mm), plant height (100cm), number of florets spike-1 (34), flowering time (39days), and vase life (6days). In a similar vein, plants treated with 30% MLE extract had the most leaves plant-1 (114), stem diameter (11mm), height (99cm), florets spike-1 (35), flowering time (44 days), and vase life (8 days) observed. In the Peshawar valley's agro-climatic conditions, it is recommended that 30% MLE for exogenous treatment and Rocket cultivar for commercial output be used.

To assess the impact of MLE (Moringa Leaf Extract) on the growth, yield, and nutritional improvement in two vegetable crops, Indian Spinach (*Basella alba*) and Tomato (*Solanum lycopersicum*), (Hoque *et al*. 2022) conducted a field study. Different frequencies of the extract were administered every two weeks. Chemical fertilizers were used to fertilize the crops, and MLE application at a rate of 25 ml per plant was carried out according to plan. The maximum frequency of application (T4) (foliar application of MLE at 2 weeks after transplanting and application every 2 weeks thereafter) had the greatest influence on each crop, significantly enhancing growth, yield, and nutrient uptake. In comparison to tomato, Indian Spinach responded proportionately more favorably to foliar-applied MLE in terms of plant growth and nutrient uptake. Indian Spinach showed a >20% increase in yield parameters compared to control, while the effect of MLE on the yield parameters was more significant in tomato, which showed a 25% increase (averaged across all the growth characteristics) above control.

According to (Yasmeen *et al*., 2012), Moringa is the most nutrient-dense tree ever discovered. To increase crop development and yields, nearly every part of the plant can be utilized as a natural bio-pesticide and an eco-friendly nutritional supplement. Based on this information, this review paper seeks to concentrate on the potential contribution of Moringa oleifera as a substitute source of the ecologically beneficial product in the production of organic vegetables. The plant has high levels of carotenoids, antibiotics, and nutrients, including vitamins and minerals. It can be used to increase the yield of various types of crops by 10-45% thanks to the high concentration of several hormones, primarily zeatin, and it also has the lowest cost of production. Numerous studies show the advantages of trees in a variety of fields, including food technology, water purification, industry, livestock production, and medicine. (Ahmed *et al*. 2020) conducted a greenhouse study to assess the development and yield of the F_1 hybrid "Hesham" cucumber (*Cucumis sativus L.*) in response to foliar applications of three doses of moringa leaf extract (1:40, 1:30, and 1:20). Following foliar application of moringa leaf extract, cucumber growth traits (plant height, leaf area, number of leaves, fresh and dry weight of leaves and stems), as well as flowering traits (number of flowers, days to the first female flower and fruit set%), were greatly improved. In response to the treatments, the growth and development of cucumber fruits (fruit fresh and dry weight, and fruits total yield) were also encouraged. Treatments with moringa leaf extract significantly raised the levels of endogenous hormones in cucumber leaves (auxins, gibberellins, and cytokinin), as well as the activity of the antioxidant enzymes catalase, peroxidase, and superoxide dismutase. This stimulating impact demonstrated that moringa leaf extract may be used as an efficient, natural, and secure biostimulant in the production of organic crops. In a field experiment, (Kanchani and Harris, 2019) investigated the effects of foliar applications of Moringa Leaf Extract (MLE) at various doses and frequencies of okra (*Abelmoschus esculentus*) plant development and yield. The treatments in this experiment were T_0 (control; distilled water), T_1 (10%) MLE at weekly intervals, T_2 (10%) MLE at biweekly intervals, T_3 (20%) MLE at weekly intervals, T_4 (20%) MLE at biweekly intervals, T_5 (30%) MLE at weekly intervals, and T_6 (30%) MLE at biweekly intervals. Each plant was sprayed with 25 ml of MLE two weeks after germination, and at 4, 6, and seven weeks after germination, the growth performance was recorded. The findings demonstrated that foliar MLE spray had a statistically significant ($p< 0.05$) influence on the okra plant's evaluated parameters compared to the control at all growth stages. The plant height, number of branches per plant, number of leaves per plant, leaf area index, dry weight of stems and roots, total biomass, number of pods/ha, and dry weight of pods all rose with MLE when 10% of the foliar spray was applied once every week. The findings imply that utilizing MLE at 10%, yield may be tripled under the experiment's conditions. Small farmers can increase their yields by using economical, environmentally safe, and low-cost moringa leaf extract as a plant growth stimulant.

2.7 Growing crops in association with Moringa

To determine how red amaranth would react in conjunction with drumstick (Moringa oleifera) saplings from February through March, Sumona (2017) undertook a field experiment at Sher-e-Bangla Agricultural University. Four treatments were used: T0= Open field, often known as the control; T_1= 12 cm from the base of the tree; T_2= 24 cm from the base of the tree; and T_3= 36 cm from the base of the tree. Red amaranth's yield-contributing traits and the growth boundaries of drumstick as affected by the management approach were also identified. At harvest, T_3 had the tallest plants of all the treatments, but it was only 9% taller than the control condition. T_1 had stems that were 22% narrower than the control condition. The T_2 treatment had the most leaves, which were 15 percent fewer than in the control condition. Red amaranth's yield-contributing features showed that treatment T_2 and T_1 had roots and shoots that were, respectively, 20% and 18% shorter than those of the control condition other than control the 1 treatment produced the highest fresh weight, dry weight, and yield. Therefore, compared to the control condition, treatment T1 resulted in 16 percent less fresh weight, 13 percent less dry weight, and 16 percent less yield. However, red amaranth's moisture content (94.27%) was highest in the T_2 treatment, whereas its dry matter content (6.38%) was highest in the T1 treatment. In the instance of drumstick, at the time of red amaranth harvest, the T_3 treatment had the greatest number of buds, while the T_2 treatment had the fewest, but the T1 treatment had the longest bud length. Therefore, it was shown that red amaranth performed best in terms of yield at treatment T1 when combined with Moringa saplings. As a result, farmers can easily produce Moringa trees alongside red amaranth while keeping a distance of 12 cm from the tree root without suffering too much loss. Arif Ahmed tested the impact of planting distances on the growth, yield, and yield-attributing traits of stem amaranth (*Amaranthus oleraceus*) during the early establishing stage of Moringa trees in 2017 at the Sher-e-Bangla Agricultural University, Dhaka. Four treatments were used in the study, each having four replications. There were four treatments: T_0 (open field as the control), T_1 (6 inches from tree base), T_2 (12 inches from tree base), and T_3 (18 inches distance from tree base). On various days after sowing (DAS) and planting distances, significant variances were seen for all characteristics. At harvest (50DAS), stem amaranth had a maximum plant height of 59 cm and a maximum number of leaves per plant of 25 cm in the control condition (T_0 treatment) and a minimum plant height of 49 cm and a maximum number of leaves per plant of 20 in the T_3 treatment. The highest shoot and root fresh weight (74 g and 16 g), shoot and root dry weight (4 g and root 1 g), and green yield (14 t/ha) was observed in open field conditions. The highest leaf length (10 cm) and leaf breadth (5 cm), stem girth (6 cm), stem length (61 cm), and root length (16 cm) were also noted (T_0 treatment). When compared to the open field condition, the yield with the T_1 treatment (12 t/ha) was 15% lower. Between November 2018 and May 2019, Roy (2019) carried out a field experiment on the agroforestry farm at Sher-e-Bangla Agricultural University, Dhaka, to investigate the interactions between brinjal growth and yield performance and the early establishment period of Moringa. Brinjal was planted on two distinct levels with four treatments: T_0 (open field plantation, considered the control), T_1 (30 cm from the tree base), T_2 (40 cm from the tree base), and T_3 (three times the distance from the tree base) (50 cm distance from the tree base). The open field plantation treatment T_0 (considered the control) had the best outcomes in terms of plant height, leaves per plant, branches per plant, plant spreading, number of fruits per plant, fruit weight per plant, single fruit weight, and yield per ha. However, for the brinjal-moringa interaction, T_3 treatment (50 cm away from the tree base) produced the best results on the relevant metrics. The T_0 (open field plantation considered as control) treatment produced the highest fruit weight per plant (1923.90 g), single fruit weight (72.60 g), and fruit yield per hectare (34.20 t), while the T_3 (50 cm distance from the tree base) treatment produced the second-highest fruit weight per plant (1592.53 g), single fruit weight (67.48 g), and fruit yield per hectare (28.31 t). T_1 (30 cm away from the tree base) treatment had the lowest fruit weight plant1 (758.11 g), single fruit weight (59.60 g), and fruit yield per ha (13.48 t). The results also showed that no tree crop contact generated the optimum output, but that when a tree crop interaction did exist, a larger distance produced a higher yield of brinjal.

2.8 Importance of Moringa leaf as Plant Growth Regulators (PGRs)

Plant growth regulators (PGRs) are powerful tools for solving production problems. However, in the specific case of organic horticultural crop production, the use of PGRs remains underdeveloped despite the enormous potential that PGRs offer for maximizing yield, optimizing fruit size and quality, and increasing net dollar return to the grower. In contrast, for a wide variety of conventionally grown horticultural crops, there are many examples of the successful use of commercially available PGRs to solve production problems.The following examples are all documented uses of PGRs in citriculture (El-Otmani *et al*., 2000) and are representative of the broad spectrum of PGR uses in horticultural crops. PGRs have been used successfully as foliar sprays to increase flowering, synchronize bloom, or change the time of flowering to avoid adverse climatic conditions or to shift harvest to a time when the market offers a better economic return. Foliar-applied PGRs are routinely used to improve fruit sets, reduce June drops, or prevent preharvest fruit drops to increase yield. PGR sprays are applied to increase fruit size directly by stimulating cell division or to increase fruit size indirectly by reducing fruit number through the application of PGRs that reduce the number of flowers formed or promote flower or fruit abscission. PGRs have been used as both pre- and postharvest treatments to increase the concentrations of nutritive and health-promoting metabolites in the edible portion of the fruit and to hasten or slow the ripening process, color development, and maturation of specific fruit tissues to improve the quality of the product sold in the market. The emerging use of PGRs to overcome the adverse effects of abiotic stress is showing great promise and might benefit the production of existing crops that are being negatively impacted by changes in climate (Javid *et al*., 2011). Surprisingly, these successes have been achieved with a modest number of commercial PGRs that are members of one of the five classic groups of plant hormones: auxins, cytokinin, gibberellins (GAs), abscisic acid (ABA), and ethylene. Hence, the tools needed by the organic horticulture industry are known but remain largely unavailable for use in commercial organic crop production.

In addition, there are only a few commercial PGRs currently labeled for use in conventional tomato production; these include the cytokinin kinetin (X-Cyte; Stoller Enterprises, Houston, TX) at 0.48 gha^{-1} in a single application to mitigate stress, including frost, drought or excessive moisture, insect or fungus infestation, or herbicide burn, or at 0.96 g ha^{-1} applied in the seedbed to promote seedling emergence, at transplanting to improve plant establishment and again 2 to 3 weeks after bloom to increase fruit set and yield (Stoller Enterprises, n.d). Gibberellic acid [GA_3 (Activol; Valent Biosciences, Libertyville, IL)] is registered for use on tomatoes in some European and South American countries, but not in the United States, to promote seedling growth, especially when temperatures are lower than normal, and to increase fruit set and fruit size. Ethylene released from ethephon (Ethrel; Bayer Crop Science, Durham, NC] is used in the field preharvest in many countries, including the United States, to prom the development and ripening of tomato fruit for the fresh market or processing (Bayer Crop Science, 2003).

In recent years, there has been significant interest in the growth-promoting potential of leaf extracts of moringa, the most commonly cultivated species in the genus Moringa in the family Moringaceae. It is a fast-growing, drought-tolerant deciduous tree native to the southern foothills of the Himalayas in northwestern India (Ramachandran et al., 1980). Moringa is widely cultivated in tropical and subtropical areas for its fruit, seeds, and leaves, which are used as vegetables, and its roots, which are used as a condiment reported to taste like horseradish [Armoracia rusticana (Ramachandran, et al., 1980)]. Moringa leaves are rich in ascorbic acid, vitamin E, phenols, and essential nutrients that not only benefit human health (Fuglie, 1999; Makkar and Becker, 1996) but also appear to contain cytokinin that improve plant growth (Foidl *et al*., 2001; Nouman *et al.,* 2012). Foidl *et al*. (2001) demonstrated that MLE increased plant biomass and dry matter content, branching, flowering, and flower retention among a wide variety of plant species. In particular, MLE increased soybean (Glycine max) yield by 35%, although the results with two varieties of black bean (Phaseolus vulgaris) were mixed (Foidl *et al*., 2001). More recent research provided evidence of the benefits of MLE for improving seed germination, biomass production, and yield of blue panicum grass (*Panicum antidote*), barnyard grass (*Echinochloa crusgalli*), buffel grass (*Cenchrus ciliaris*), wheat (*Triticum aestivum*), and maize (*Zea mays*) (Afzal *et al*., 2012; Nouman *et al*., 2012; Yasmeen et al., 2013). It was undertaken to compare the potential benefits of a foliar or root application of MLE with those provided by cytokinin for increasing vegetative growth, yield, and fruit quality components, such as the fruit size, of tomato. MLE also protected maize from low-temperature stress (Afzal *et al*., 2012) and wheat from salinity stress (Yasmeen *et al*., 2013)

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted to evaluate the responses of Moringa leaf extract to the growth and yield of tomato. The materials followed methodologies, and other relevant activities during the experimental period are elaborately represented in this chapter. A brief description of the experimental site, season, soil, weather and climate, land preparation, fertilizer application, experimental design, preparation of Moringa leaf extract, collection of seedlings, data collection procedure and statistical data analysis, planting material, intercultural operation, etc. are included here. The experiment was carried out with single-phase growth and yield in the pot.

3.1. Location and time

The experiment was conducted at the Agroforestry Field Laboratory under the Department of Agroforestry and Environmental Science, Sher-e-Bangla Agricultural University, Dhaka During the period from January 2021 to April 2021. The location of the site is 23°75′ N latitude and 90°34′ E longitude with an elevation of 8.45 meters from sea level.

3.2. Weather and Climate

The experimental site is situated under a winter climate that is characterized by low rainfall from January to April. The rate of annual rainfall, minimum and minimum temperature, relative humidity, and other relevant information were collected from Bangladesh Meteorological Department.

3.3. Soil Characteristics

The research work was carried out on a high land belonging to the AEZ 28, Madhupur tract (Tejgaon soil series). The structure of the soil was fine with an organic carbon content of 0.45%. The texture was silty clay with a pH of 5.6. The general soil type was non-calcareous dark grey. The experimental area was on medium to high land above the flood level.

3.4. Planting Materials

In this experiment, Moringa leaf extracts were collected from the Agroforestry field laboratory under the Department of Agroforestry and Environmental Science, Sher-e-Bangla Agricultural University, Dhaka which was established 1 year ago. The seedling of Tomato (*Solanum lycopersicum*), (BARI Tomato-15) was purchased from the horticulture Centre, DAE, Asad gate, Dhaka.

3.5. Experimental Design and Treatment Combination

The single-factor experiment was conducted in the pot. The experiment was carried out following a randomized complete block design (RCBD) with four replications. Six treatments that were used in this experiment are as follows:

1. T_0= Control (Without Moringa leaf extract)
2. T_1= Moringa extract sprayed at 10ml
3. T_2= Moringa extract sprayed at 20ml
4. T_3= Moringa extract sprayed at 30ml
5. T_4= Moringa extract sprayed at 40ml
6. T_5= Moringa extract sprayed at 50ml

	Block1	Block2	Block3	Block4	Block5	Block6	
	T_0R_1	T_1R_1	T_4R_1	T_3R_1	T_2R_2	T_5R_1	
	T_0R_2	T_3R_2	T_2R_2	T_1R_2	T_4R_2	T_5R_2	
	T_2R_3	T_1R_3	T_3R_3	T_0R_3	T_4R_3	T_5R_3	
	T_0R_4	T_5R_4	T_2R_4	T_3R_4	T_4R_4	T_1R_4	

Figure: 1 Layout of Experiment Field

3.6. Pot Preparation

Topsoil was collected from the experimental field and then pulverized. The inert materials visible insects, pests, and weeds were removed. Then the soil was dried thoroughly. Cow dung, Urea, and TSP per pot were incorporated uniformly into the soil. Clean and dried soil pots of 14-liter size were used for the experiment. Each pot was filled with 10 kg of previously prepared soil.

3.7. Preparation of Moringa Leaf Extract and Treatment Procedure

Moringa fresh leaves were collected, air-dried, and milled with a grinding machine. 20g of the milled leaves were mixed with 675ml of 80% aqueous ethanol. The extract was diluted in distilled water at a ratio of 1:20 (Makkar and Becker, 1996). By following this formula, a 600ml working solution was prepared to spray the Tomato plant every treatment at 7 days intervals. For the preparation of 600ml working solution, Moringa leaves extract was used at 30ml, ethanol 20ml, and water 550ml. Moringa leaf extract was added to the pot at the rate of (control), 10ml, 20ml, 30ml, 40ml, and 50ml at one-week intervals.

3.8. Collection of Seedling

Seedlings of Tomato (BARI Tomato-15) were collected from a nursery bed at Horticulture Research Centre, DAE, Asad gate, Dhaka. Total 50 tomato seedlings were taken. Two seedlings were transplanted to each pot four weeks after emergence. The seedlings were later thinned to one seedling per pot a week after of transplant.

3.8.1. Crop Establishment and Management

Tomato seedlings (BARI Tomato-15) were transplanted into the experimental pot on 3rd January 2021.

3.8.2. Management Practice

3.8.3. Fertilizer Application

Chemical fertilizers were used with proper doze along with cow dung applied to the experimental pot during final pot preparation.

3.8.4. Weeding and Irrigation

Weeding was done as necessary to keep the pots free from weeds during the experimental period. To maintain optimum soil moisture all pots were irrigated as necessary by using a watering cane.

3.8.5. Pest and Disease Management

Pesticide and Insecticide were applied to the crops in proper doze two times, 15 days interval.

3.8.6. Data Collection

The following data on the growth and yield of Tomato were collected

1. Plant height (cm)
2. Number of leaves per plant
3. leaf length per plant (cm)
4. Days to 1st flowering
5. Days to 1st fruiting
6. Number of fruits per plant after 48 days
7. Fresh weight of shoot (g)
8. Fresh weight of root (g)
9. Dry weight of shoot (g)
10. Dry weight of root (g)
11. Single fruit weight (g)
12. Fruit yield per pot (g)
13. Fruit Yield per ha (t)

The procedure of recording data

3.9.1. Plant height (cm):

Plant height was measured in centimeters (cm) by using a scale at 30, 45, 60, 75, and 90 DAT from the ground level to the tip of the plant leaf.

3.9.2. Number of leaves per plant:

Several leaves of each plant were counted at the vegetative and fruiting stages. All the leaves of each plant were counted separately. Only the smallest young leaves at the growing point of the plant were excluded from counting. The average number of leaves of four replications gave the number of leaves per treatment.

3.9.3. Days to 1st flowering:

The interval between transplanting to 1st flowering from each replication was calculated and expressed in days.

3.9.4. Days to 1st fruiting: The interval between transplanting to 1st fruiting from each replication was calculated and expressed in days.

3.9.5. Fresh weight of shoot (g):

After harvesting, four plants were selected from each treatment per pot. Then shoot weight was weighted separately by balance. The sum of the fresh weight of 4 plants was divided by 4. Then it was recorded as the fresh weight of a single plant. The fresh weight of the shoot was expressed in gram (g).

3.9.6. Dry weight of shoot (g):

After harvesting, selected plant shoots were put into a paper packet and placed in an oven, and dried at 60°C for for 72 hours. The sample was then transferred into desiccators and allowed to cool down to room temperature and then the final weight of the sample was taken. Average weight was measured gram (g) and expressed as dry weight per plant.

3.9.7. Fresh weight root (g):

After harvesting, 4 plants were selected from each treatment per pot, and the root was separated. Then root weight was weighted separately by balance. The sum of the fresh weight of 4 plants' roots was divided by 4. Then it was recorded as the fresh weight of root per plant. The freshest weight of root was expressed in gram (g).

3.9.8. Dry weight of root (g):

After harvesting, selected plant roots were put into a paper packet and placed in an oven, and dried for 60°C for for 72 hours. The sample was then transferred into desiccators and allowed to cool down to room temperature and then the final weight of the sample was taken. Average weight was measured in gram (g) and expressed as dry root weight per plant.

3.9.9. Number of fruits per plant:

A total number of fruits were counted of harvest from the selected plants from each treatment per pot and the average value was expressed as the number of fruits per plant.

3.9.10. Single fruit weight (g)

Based on five representative fruits, individual fruit weight in grams was calculated.

3.9.11. Fruit yield pot^{-1} (kg)

The total fruit weight of whole plants in each pot was recorded and yield per pot was calculated.

3.9.12. Fruit yield (t ha^{-1})

It was measured by the following formula,

$$\text{Fruit yield (t ha}^{-1}\text{)} = \frac{\text{Fruit yield per pot (kg)} \times 42000}{1000}$$

3.10. Statistical Analysis of data

The data obtained for different parameters were statistically analyzed to observe the significant difference among the treatment. The mean value of all the parameters was calculated and an analysis of variance was performed. The recorded data on different parameters were statistically analyzed by using SPSS version 23 software to find out the significance of variation resulting from the experimental treatment. The mean values for all the treatments were accomplished by the Duncan test. The significance of the difference between the pair of means was tested at 5% and 1% levels of probability.

CHAPTER 4

RESULTS AND DISCUSSION

Data obtained from the present study was presented and discussed in this chapter through different Tables and Graphs. The current experiment went through the effect of Moringa leaf extract on the growth and yield of tomato. The results of the experiment are presented and discussed with the following headings and sub-headings.

4.1 Results

4.1.1 Growth parameters

4.1.2 Plant height

Plant height is one of the important growth characteristics of Tomato plants. Significant variation was found in the plant height of tomatoes due to the use of different levels of Moringa leaf extract (Table 1). The plant height was increased gradually with the advancement of crop growth up to the final harvest. At 30 DAT, the plants belonging to the open field in pot condition (T_5) exhibited the highest plant height (25.25 cm) which was statistically different from the plant height recorded in T_0, T_1, T_2, T_3, T_4, and T_5 treatments where the lowest tomato plant height (9.70 cm) was found from T_0 treatment. At 45 DAT, significantly the highest Tomato plant height (45.75 cm) was observed in the T_5 treatment which was statistically identical T_4 treatment where both were significantly higher than other treatment combinations followed by T_0, T_1, T_2, and T_3. The lowest plant height at 45 DAT (17.75 cm) was recorded in plants grown to use 0ml of the Moringa leaves extract based on T_0 treatment. A similar trend was found at 60, 75, and 90 DAT. Results revealed that at 60, 75, and 90 DAT, the highest plant height (55 cm, 60.75 cm, and 62 cm, respectively) was recorded from the treatment T_5 which was statistically identical to T_4 treatment where the lowest plant height (31.25 cm, 41.50 cm, and 41.75 cm, respectively) was obtained from T_0 treatment.

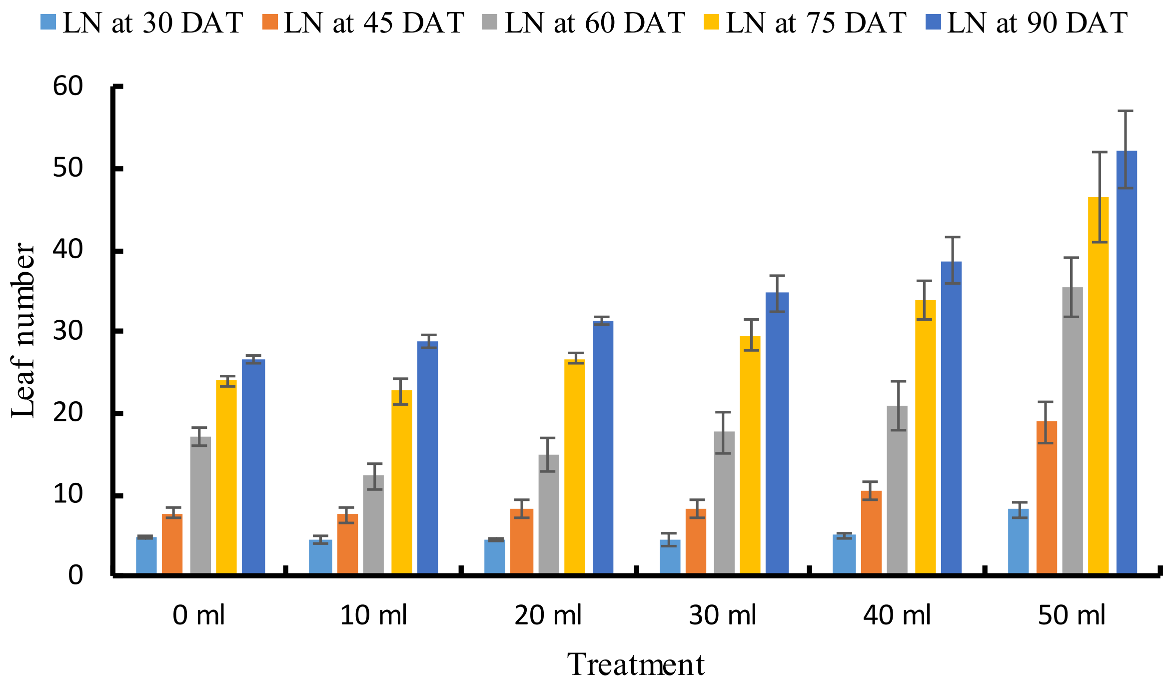
Table 1. Effect of Moringa leaf extract on Plant height(cm) of Tomato

Treatment	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
T_0	9.70 c	17.75 bc	28.25 b	41.50 c	42.00 c
T_1	10.50 c	18.25 bc	31.00 b	35.75 c	43.00 c
T_2	10.63 c	20.75 c	33.00 b	44.50 bc	46.00 c
T_3	11.13 c	22.63 bc	35.75 b	46.75 bc	52.00 b
T_4	15.63 b	27.75 b	38.75 b	52.00 ab	55.00 b
T_5	20.25 a	45.75 a	51.00 a	54.75 a	62.00 ab
Level of significance	**	**	**	**	**
SE(±)	0.91	2.43	2.57	2.09	2.15

** Note: Significant at 1% levels of significance
DAT = Days After Transplanting
T_0 = (Control), T_1= 10 ml Moringa leaves extract,
T_2 = 20 ml Moringa leaves extract, T_3 = 30 ml Moringa leaves extract,
T_4 = 40 ml Moringa leaves extract, T_5 = 50 ml Moringa leaves extract.

4.1.3 Number of leaves per plant

Under different treatments, the number of leaves per plant exhibited different results. A statistically significant difference was observed among the treatments on the number of leaves per plant at different DAT (Table 2). A tomato grown with Moringa leaves extract (T_5 treatment) produced the highest number of leaves per plant at all growth stages which was significantly higher than other treatments where Tomato plants were grown at different concentrations of Moringa leaves extract. Similarly, at 30 DAT, the T_5 treatment showed the highest number of leaves per plant (8.25) compared to other treatments followed by the T_5 treatment whereas the lowest number of leaves per plant (4.75) was recorded in treatment T_0. At 45 DAT, 60 DAT, 75 DAT, and 90 DAT similar tendencies were found for several leaves per plant, and the highest (19.00, 35.50, 46.50, and 52.25 at 45 DAT, 60 DAT, 75 DAT, and 90 DAT, respectively) number of leaves were found in the Tomato plants under T_5 treatment which was closely followed by T_4 treatment whereas the lowest number of leaves per plant (7.75, 17.25, 24.00 and 26.75 at 45 DAT, 60 DAT, 75 DAT, and 90 DAT respectively) was recorded in the plants under T_0 treatment.



4.1.4. Leaf Length

One of the key growth traits of tomato plants is leaf length. Tomato leaf length varied significantly as a result of the usage of various concentrations of moringa leaf extract (Table 2). Up until the final harvest, the leaf length gradually increased as the crop grew. The plants in pot condition (T_5) had the tallest leaf length at 30 DAT (5 cm), which was statistically different from the leaf length seen in the T_0, T_1, T_2, T_3, T_4, and T_5 treatments, where the tomato plants had the shortest leaf length (4.75 cm) at that time. At 45 DAT, the T_5 treatment substantially had the highest tomato leaf length (19 cm). The T_5 treatment, which was statistically identical to the T_4 treatment and considerably higher than other treatment combinations at 45 DAT, had the highest tomato leaf length (10.5 cm). T_0, T_1, T_2, and T_3 were the next highest treatments. The plants grew to use 0ml of the Moringa leaves extract based on T_0 treatment (control) and had the lowest leaf length at 45 DAT (7.75 cm). At 60, 75, and 90 DAT, a comparable pattern was discovered. Results showed that the treatment T_5, which was statistically identical to the T_4 treatment, which produced the lowest leaf length (17.25 cm, 24 cm, and 26.75 cm, respectively) at 60, 75, and 90 DAT, recorded the highest leaf length (35.50 cm, 46.50 cm, and 52 cm, respectively).

Table 2. Effect of Moringa leaf extract on leaf length(cm) of Tomato

Treatment	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
T_0	4.50 b	7.75 b	12.25 bc	20.00 c	26.75 d
T_1	4.50 b	7.50 b	14.25 c	22.75 c	28.75 cd
T_2	4.50 b	8.25 b	15.00 bc	26.75 bc	31.25 bc
T_3	4.50 b	8.25 b	17.75 bc	29.50 bc	34.75 bc
T_4	4.50 b	10.50 b	21.00 b	33.75 b	38.75 b
T_5	5.00 a	19.00 a	35.50 a	46.50 a	52.25 a
Level of significance	**	**	**	**	**
SE(±)	0.35	0.99	1.80	1.93	1.98

** = Significant at 1% levels of significance
DAT = Days After Transplanting

4.1.5 Yield contributing parameters and yield

4.1.5.1 Days to 1st flowering

First flowering defines the initiating of production. Days to 1st flowering differ significantly among the treatments (Figure 3). Results indicated that the highest days to 1st flowering were recorded in the T_0 treatment (49.75 days) which was significantly different from other treatments followed by T_1, T_2, T_3, T_4, and T_5. The lowest days to 1st flowering (39.50 days) were recorded in plants under T_5 treatment which was significantly similar as T_4.

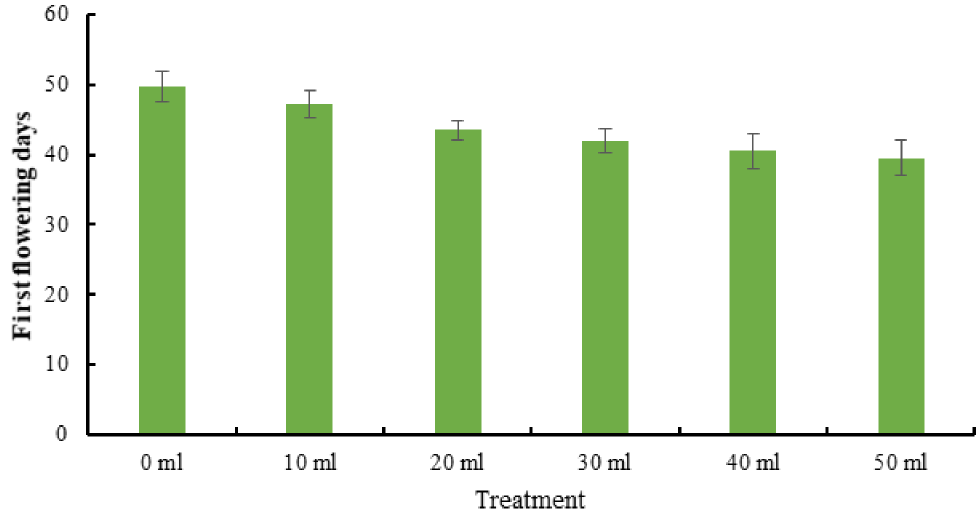


Figure 3. Effect of Moringa leaves extract on First Flowering Days of Tomato

4.1.5.2 Days to 1st fruiting

There was significant variation in days to 1st fruiting of Tomato at different treatments of Tomato and Moringa leaf extract solution (Table 2). Results Revealed that the highest days to 1st fruiting (55.25 days) were recorded in T_0 treatment which was significantly different from other treatments whereas the lowest days to 1st fruiting (44.25 days) were found in T_5 treatment which was statistically the same with T_4 treatment.

Table 3. Effect of Moringa leaves extract on 1st fruiting days of Tomato

Treatment	First Fruiting days
T_0	55.25 a
T_1	53.00 ab
T_2	51.00 abc
T_3	49.25 abc
T_4	46.75 bc
T_5	44.25 c
Level of Significance	**
SE(±)	1.09

** = Significant at 1% levels of significance
DAT = Days After Transplanting

4.1.5.3 Fresh weight of shoot (g)

Shoot fresh weight per plant of Tomato plant was observed significantly different among treatments (Figure 3). The best result (169.50 gm) for fresh weight was found for T_5 treatment. The second highest result (160.50 gm) was recorded in the T_4 treatment which was statistically similar to T_5 treatment. The minimum result (85.75 gm) was recorded in the Tomato plant with T_0 treatment in the control condition.

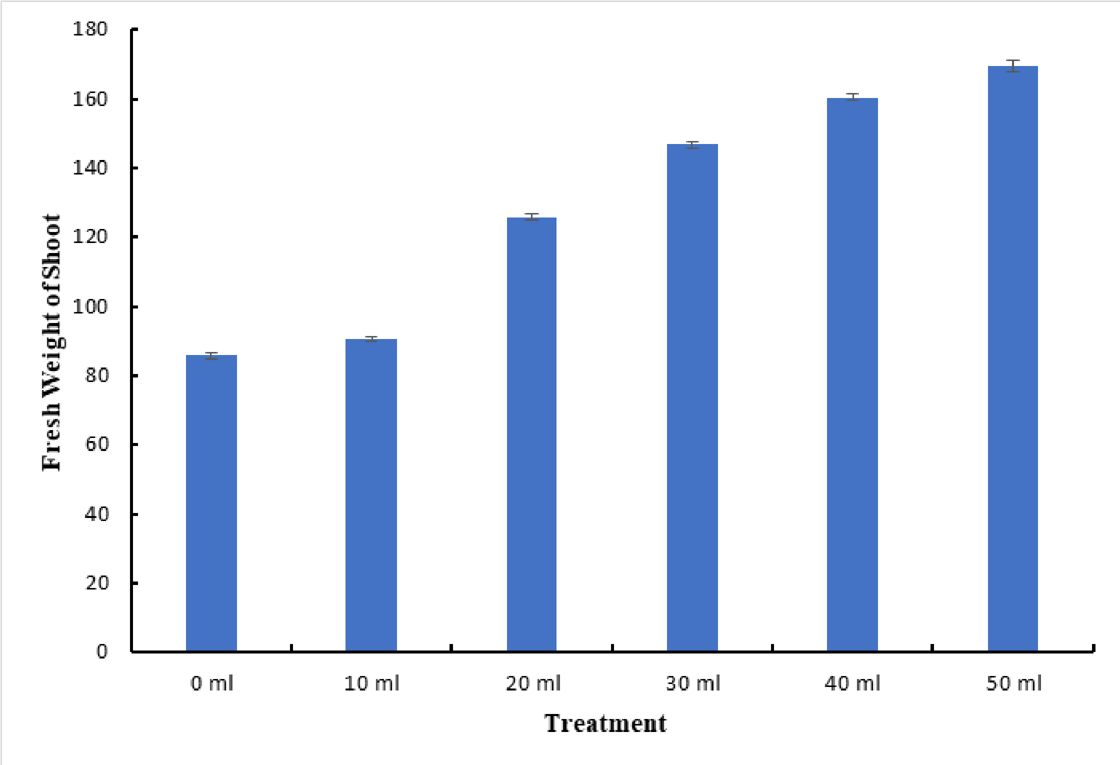


Figure:4. Effect of Moringa leaves extract on Fresh weight of shoot of tomato

4.1.5.4 Fresh weight of Root (g)

Statistically, significant variation was found in root fresh weight of Tomato by Moringa extract and Tomato interaction regarding the varied concentration of Moringa leaf extract of solution (Table 4). The height amount of fresh weight of root (12.75 gm) was recorded in the T_5 treatment whereas the lowest fresh weight of root (5.18 gm) was recorded in the T_0 treatment.

Table 4. Effect of Moringa leaves extract on fresh weight of Root of Tomato

Treatment	Fresh weight of Root (g)
T_0	5.18 f
T_1	6.13 e
T_2	7.33 d
T_3	8.23 c
T_4	10.88 b
T_5	12.75 a
Level of Significance	**
SE(±)	0.60

** = Significant at 1% levels of significance

4.1.5.5 Dry weight of shoot (g)

Various concentrations of Moringa leaf extract solution with the association of Tomato plant effect on shoot dry weight Tomato (Figure 4). For all of the treatments, the height dry weight of the shoot (29 gm) was recorded in pot condition T_5 treatment whereas the lowest dry weight of the shoot (15.23 gm) was recorded in T_0 treatment.

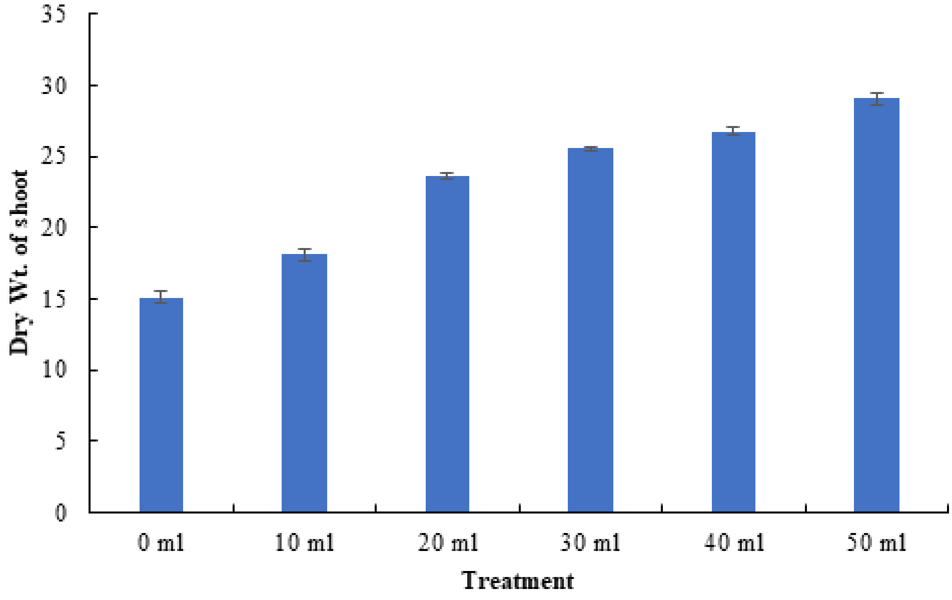


Figure:5. Effect of Moringa leaves extract on Dry weight of shoot of tomato

4.1.5.6 Dry weight of Root (g)

Root dry weight of Moringa was statistically significant by Moringa leaf extract Tomato interaction regarding the varied different concentrations of Moringa solution (Table 5). The height and dry weight of the root (4.47 gm) were recorded in open field conditions in pot treatment T_5 since the lowest dry weight of the root (2.02 gm) was recorded in treatment T_0.

Table 5. Effect of Moringa leaves extract on Dry weight of Root of Tomato

Treatment	The dry weight of Root(g)
T_0	2.03 f
T_1	2.53 e
T_2	3.18 d
T_3	3.63 c
T_4	4.05 b
T_5	4.48 a
Level of Significance	**
SE(±)	0.18

** = Significant at 1% levels of significance

4.1.5.7 Number of fruits per plant

Due to different concentrations of Moringa leaf extract solution the Tomato plant tree had a significant influence on the number of fruits per plant (Figure 5). The highest number of fruits per plant (24) was recorded in pot condition T_5 treatment while the lowest number of fruits per plant (7.75) was recorded in plants under T_0 treatment.

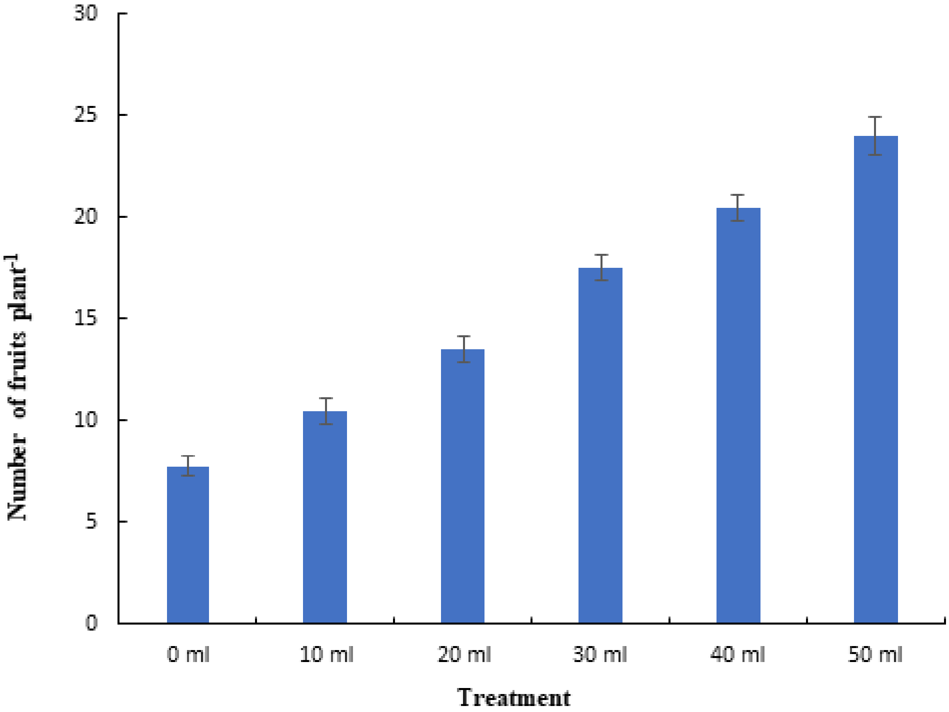


Figure:6. Effect of Moringa leaves extract on the Number of fruits plant^{-1} of tomato

4.1.5.8 Fresh fruit Weight plant^{-1}

Significant influence was found on individual fruit weight due to different concentrations of Moringa leaf extract on the Tomato plant (Table 6). The highest individual fruit weight (65 g) was recorded in the open field in pot condition T_5 treatment as the lowest individual fruit weight (44.48 g) was recorded in plants under treatment T_0.

Table 6. Effect of Moringa leaves extract on the single weight of fruit per plant of tomato

Treatment	Single Fruit Wt. $Plant^{-1}$(gm)
T_0	44.78 f
T_1	49.30 e
T_2	52.05 d
T_3	56.23 c
T_4	61.65 b
T_5	65.00 a
Level of Significance	**
SE(±)	1.46

** = Significant at 1% levels of significance

4.1.5.9 Yield of Tomato

Yield is the final main product of Tomato plants. Significant variation was found in the production of tomatoes due to the use of different levels of Moringa leaves extract solution (Table 7). The highest fruit yield (70.2 t ha^{-1}) was recorded in the T_5 treatment as the lowest fruit yield (31.5 t ha^{-1}) was recorded in plants under treatment T_0.

Table 7. Effect of Moringa leaf extract on yield of Tomato

Treatment	Yield (NFP^{-1} × $SFFWt.P^{-1}$) t ha^{-1}
T_0	31.5 f
T_1	39.0 e
T_2	42.18 d
T_3	44.28 c
T_4	57.15 b
T_5	70.2 a
Level of Significance	**
SE(±)	3.16

** = Significant at 1% levels of significance

NPF^{-1} = Number of fruits $plant^{-1}$

$SFFWt.P^{-1}$ = Single fresh fruit weight $plant^{-1}$

4.2 Discussion

The treatment evaluated in this study varied not only in yield ability but also in all the agronomic traits measured. Based on reports in earlier studies, the present study included a variety of commonly cited traits including plant height of Tomato, number of branches, fruit diameter, individual fruit weight, fruit yield, and canopy spreading of Moringa. Significant variations among the treatment were recorded suggesting that selection based on those traits was practical. The increase in plant parameters namely; the plant height, leaves number, number of branches, and number of flowers as a result of extracts used in this research significantly increased the growth of tomato plants used in this research. This luxuriant growth of the tomato plants might be due to the volume of concentration (up to 50 ml) of *Moringa oleifera* extracts used. The magnitude of the increase that appeared might depend mainly on the concentrations used, and the increase the yield a simultaneous increase up to the limit in the above growth parameters. Plant extracts of some trees and crop residues have been reported to influence crop growth and yield of vegetable crops (Ahmed and Nimer, 2002; El Atta and Bashir, 1996; Chung and Miller, 1995). Leaf extracts of *Moringa oleifera* have been reported to accelerate the growth of young plants, strengthen plants, increase leaf area duration, increase the number of roots, produce more and larger fruits, and generally increase yield by 20 to 35% (Fuglie,2000). It has been established in this research that in T_5 treatment, plant height was initially 20.25 cm, which increased to 45.75 cm, 55 cm, 60 cm, and 58 cm and leaf numbers also increased to 5, 19, 35.50, 46.50, and 52.25 respectively. It could be deduced that the chemical components incorporated in the extracts used might be responsible to inhibit the development of these tomato plants in comparison with the control treatments. Both the plant height and leaf number increase with the constant application of the Moringa leaf extracts at 50 ml concentrations with regular plant height (58 cm) and leaf number (52.25). This could also be explained that Moringa leaf extracts enhanced the germination of tomato plants by 20-80%. (Becker *et al.*, 2001) reported that aqueous extract of Moringa at the ratio of 1:10 (w/v) prepared in a 30 g of plant leaf material with 300 ml of distilled water was found to influence the duration of height and hypocotyls growth in tomato and sorghum. The leaf extracts of Moringa also gave higher (100%), vigorous, and good quality tomato seedlings in height, leaf number, and flowering. Schon and Einhellig (1990), demonstrated that incorporation of dried sunflower leaf material into the soil; treatment with aqueous extract, root exudates, and leaf leachates inhibited germination and growth of grain sorghum (*Sorghum bicolor*).

This could be explained by the fact most of the tomato plants grown in the trials are highly sensitive to the extracts used followed by the influence of the weather and condition of the soils which may seem to be more in retaining moisture contents and leaf extracts. The improvement in growth parameters of tomato plants in response to the shikimic acid application is mediated through the increased longevity of leaves and branches by retaining chlorophylls and increasing mineral contents which perhaps contributed to increased plant growth (Zakaria and Razak, 1990). In addition, the results obtained here are by the results of Burnside et al. (1994), who stated that seed priming with shikimic acid and Moringa root extract increased the growth and yield of cowpea plants grown under greenhouse conditions through photosynthetic activity.

In this work, it was reported that treatment T_5 had the highest number of growth parameters of the tomato plants. It was, therefore, found to be the most appropriate concentration for increasing the healthy vegetative growth and parameters of the tomato plants. This was probably due to the high concentration of the growth-promoting substances contained in this treatment. The effect of Moringa leaves extract in stimulating plant growth was reported (Fites *et al*., 1982).

It was also observed that treatment T_5 (90 DAT) highest plant height, leaves number, and a number of fruits of 62 cm, 52, and 24 respectively. This indicates that a reduction in the concentration of *Moringa oleifera* leaves extract might have affected the growth of tomato plants. It was also observed that treatment T_4 (75 DAT) followed with the highest plant height, leaves number, and the number of fruits of 60.50 cm, 46.50, and 20.50 respectively. It was also observed in treatment T_1 (30 DAT) followed by the tallest plant height, leaves number, and the number of fruits of 10.50 cm, 4.5, and 10.50 respectively having the least growth-promoting substances among treatments with Moringa leaves extract. Treatment T_0 (Control), 90 DAT was found to have the least of all the growth parameters with the lowest plant height, leaves number, and the number of fruits of 38.50cm, 26.75, and 7.75 respectively. Meanwhile, those that were not statistically different from the controls might be due to inhibition of the growth of tomato plants which is generally related to changes in the plant's water status and ability to retain the leaf extracts.

This supports the report of Chiteka *et al*. (2012), who noticed that, the application of Moringa root and leaf extract by 2-4 weeks after planting significantly ($p<0.05$) increased fresh fruit weight and several stems, flowers, and branches of the tomato plants. Plant residues often contain a variety of toxins that are known inhibitors of seed germination or seedling growth (Chov and Patrick, 1976). Recycling crop residue and leachates from plants to the soil have been reported to inhibit seed germination and vegetative propagules, and early seedlings' growth in tomatoes. With this vision, Dhwan and Gupta (1996), applied Moringa leaf extracts in the ratio of 1:10 (w/v) on seeds of maize, rice, sorghum, and wheat in a growth room at 25°C for 14 days and found that it did not only increase the length of radical but also increased hypocotyl length of maize and wheat. It was reported that this hormone application as a seed treatment not only improved the vegetative growth but also enhanced the grain yield even applied in very small amounts as a seed treatment.

In moringa, there is zeatin hormone in very high concentrations of between 5 mcg and 200 mcg/g of material. Fuglie (2000), confirmed that this cytokinin (CK) related hormone increases crop yields when sprayed as an extract from fresh moringa leaves. The extract from the drumstick has a high plant hormone group cytokines (Makkar and Becker, 1996) anti-oxidant activity. Moreover, which is known for stay green and stress moringa leaf extract is enriched with tolerance capabilities. zeatin, a purine adenine derivative of cytokine in promoting cell division and elongation, and also Moringa leaf extract when applied for drought or salt-stressed plants modified plant phenotypic response positively affects growth and productivity with alteration in the metabolic process. Moringa leaf extract, when applied to tomatoes, increased plant height, and the number of leaves and hastens the days of the flower. This was attributed to moringa leaf extract being rich in zeatin, a cytokine that maintained the green photosynthesis area, therefore contributing to higher fruit yield (Price, 2007). Foliar application of Moringa leaf extract can be used effectively to improve the fruit set, yield, and fruit weight of Tomato and Okra (Reddy *et al*., 1992).

CHAPTER 5

SUMMARY AND CONCLUSION

5.1 SUMMARY

The experiment was conducted at the Agroforestry farm of Sher-e-Bangla Agricultural University, Dhaka during the period from January 2021 to April 2021 to study the performance of Tomato growth and yield in Moringa leaf extract solution. The results were presented on growth, yield, and yield-attributing characteristics of Tomato as influenced by Moringa extract at a different level of treatment. The experiment consisted of six treatments *viz*. T_0, T_1, T_2, T_3, T_4, and T_5. The experiment was laid out in Randomized Complete Block Design (RCBD) comprising four replications. The seedling of Tomato (var. BARI Tomato-15) at Horticulture Research Centre, DAE, Asad gate, Dhaka and transplanted in the main field with 30-day-old seedling of Tomato. Data were collected on Tomato plant height, number of leaves, leaf length per plant, days to 1^{st} flowering, days to 1^{st} fruiting, days to complete harvest, number of fruits per plant, fruit yield per plant, individual fruit weight, fruit yield per pot and fruit yield per ha. The collected data were analyzed statistically and the differences between the means were evaluated by SPSS Methods.

Growth and yield attributing parameters were highest in T_5 treatment compared with other treatments where Tomato plants were grown at different concentrations of Moringa leaf extract solution. The results of the experiment showed that the different treatments had a significant effect on all the parameters tested.

The highest plant height (62 cm) was observed in the T_5 treatment and the lowest plant height of Tomato (38.50 cm) was recorded in the T_0 (control) treatment. Among the treatments, the 2^{nd} highest plant height (55.75 cm) was found in the T_4 treatment. As expected, the maximum number of leaves per plant at 90 DAT (52.) was observed in the T_5 treatment, which was significantly highest than all other treatments. Among the treatment, the 2^{nd} height number of leaves per plant (38.78) was recorded in the plants belonging to the T_4 treatment. However, the lowest number of leaves per plant (26.75) was recorded in the T_0 treatment.

In terms of yield contributing parameters and yield, with Moringa extract and Tomato plant interaction T_5 showed the lowest days to 1st flowering (39.50 days) and T_4 showed the 2^{nd}

lowest days (40.50 days) whereas the highest days to flowering achieved from T_0 treatment (49.75 days).

Again, the highest number of fruits per plant (24), individual fruit weight (65 g) and fruit yield ha^{-1} (70.2 t) were also found in an open field in pot condition (T_5 treatment). And the 2nd higher number of fruits per plant (20.50) and individual fruit weight (61.65 g) and fruit yield ha^{-1} (57.15 t) were obtained from T_4 treatment. On the other hand, the lowest number of fruits per plant (7.75), individual fruit weight (44.78 g) and fruit yield ha^{-1} (31.5 t) were obtained from the T_0 treatment.

Based on observed data points, predicted optimum Moringa leaf extract on tomato plant gives maximum Tomato yield.

5.2 Conclusion

The yield performance of Tomato was influenced significantly due to different concentrations of Moringa leaf extract. The findings of the experiment concluded that open field in pot conditions T_5 treatment exhibited the highest results in respect of growth and yield of Tomato. The second highest yield was observed in the T_4 treatment compared to T_3, T_2, and T_1 treatments which was higher than the control condition. And lowest yield was observed in the T_0 treatment. Therefore, this study showed the best yield (70.2 t ha^{-1}) performance of Tomato at treatment T_5 treatment with 50 ml Moringa leaf extract. Tomato and Moringa leaf extract had a strong positive relationship with all maximum parameters. Based on observed data points, the enumerated maximum (dose 50 ml) concentration of moringa leaf extract donates optimum Tomato yield (70.2 t ha^{-1}). Thus, farmers can cultivate Tomato with Moringa leaf extract solution and should use dose of 50 ml concentration for getting optimum yield.

Recommendations

All the data generated in this study were based on one trial which was conducted from 0 to 4 months of Tomato plant. Therefore, to conclude, a repeated trial of tomatoes should be conducted with the Moring leaf extract solution. Moringa leaf extract should be foliar and soil sprayed with other Rabi and Kharif vegetables to know the Moringa-vegetables relation more precisely.

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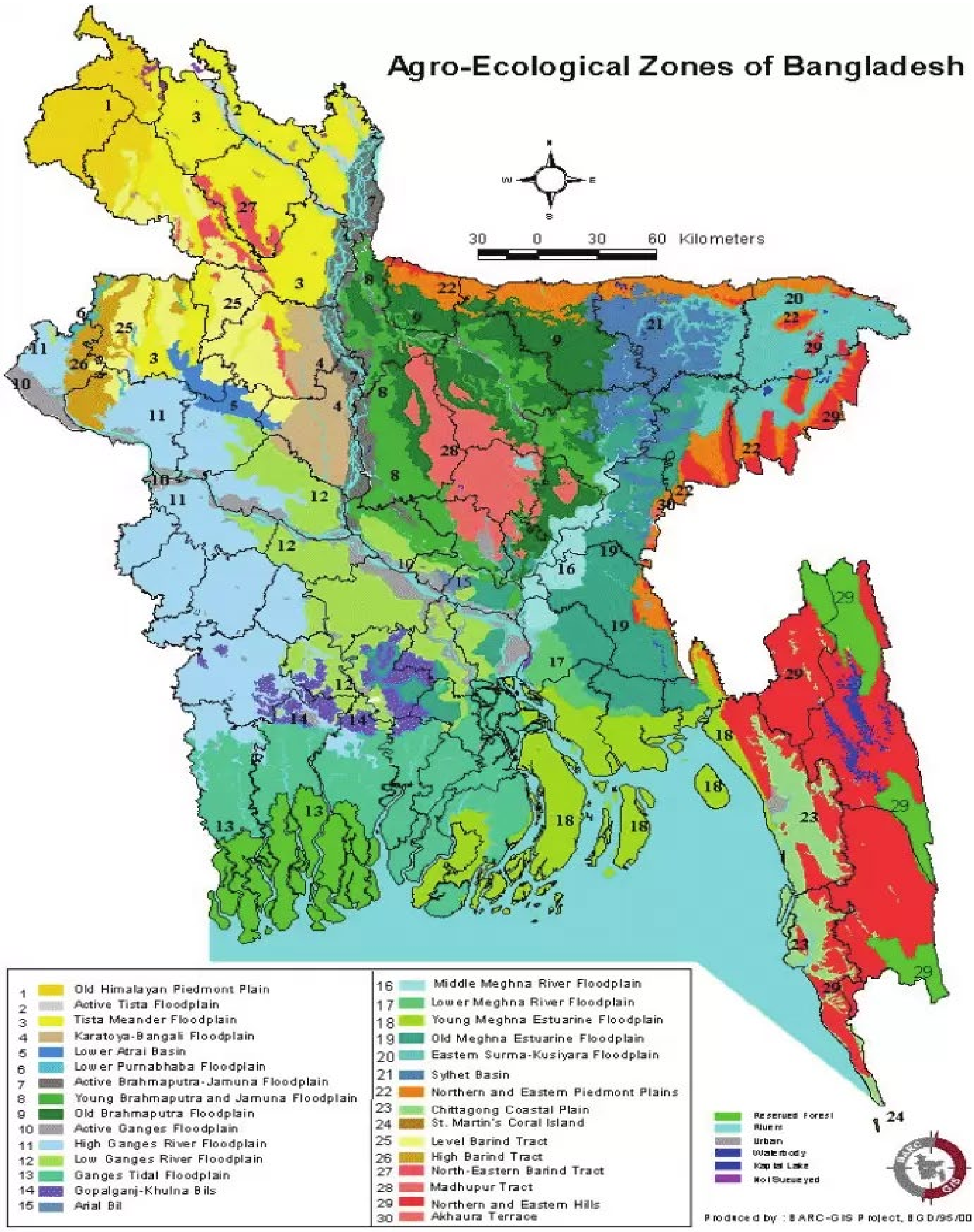
APPENDICES

Appendix I: Agro-Ecological Zone of Bangladesh showing the experimental location



Appendix II: Monthly meteorological information during the experimental period

Year	Month	Air temperature(^{0}C)		Relative humidity (%)	Total Rainfall (mm)	Sunshine (hr)
		Maximum	Minimum			
2021	January	24.60	13.50	68.50	00	5.7
	February	28.90	18.00	67	30	6.7
	March	33.60	29.50	54.70	11	8.2
	April	33.50	25.90	64.50	119	8.2

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Agroforestry Farm, SAU, Dhaka
AEZ	Madhapur Tract (28)
General Soil Type	The shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	Value
Particle size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
Ph	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Department of Soil Science, SAU.

Appendix IV. Analysis of variance of data on plant height of Tomato influence by different concentrations of Moringa extract solution

Plant Height	Group	Sum of Squares	df	Mean Square	F	Sig.
30DAT	Between Groups	342.977	5	68.595	11.175	.00
	Within Groups	110.492	18	6.138		
	Total	453.470	23			
45DAT	Between Groups	2521.469	5	504.294	12.301	.00
	Within Groups	737.938	18	40.997		
	Total	3259.406	23			
60DAT	Between Groups	2079.708	5	415.942	4.774	.01

	Within Groups	1568.250	18	87.125		
	Total	3647.958	23			
75DAT	Between Groups	1535.708	5	307.142	6.367	.00
	Within Groups	868.250	18	48.236		
	Total	2403.958	23			
90DAT	Between Groups	1869.833	5	373.967	9.820	.00
	Within Groups	685.500	18	38.083		
	Total	2555.333	23			

**= 1% level of significance

Appendix V. Analysis of variance of data on Number of leaves of Tomato influence by different concentrations of Moringa extract solution

Number of Leaves	Group	Sum of Squares	df	Mean Square	F	Sig.
30 DAT	Between Groups	44.00	5	8.80	7.040	.00
	Within Groups	22.50	18	1.25		
	Total	66.50	23			
45 DAT	Between Groups	393.71	5	78.74	9.964	.00
	Within Groups	142.25	18	7.90		
	Total	535.96	23			
60DAT	Between Groups	1354.71	5	270.94	11.257	.00
	Within Groups	433.25	18	24.07		
	Total	1787.96	23			
75DAT	Between Groups	1535.71	5	307.14	10.627	.00
	Within Groups	520.25	18	28.90		
	Total	2055.96	23			
90DAT	Between Groups	1727.33	5	345.47	14.246	.00
	Within Groups	436.50	18	24.25		
	Total	2163.83				

**= 1% level of significance

Appendix VI. Analysis of variance of data on first flowering of Tomato as an influence by different concentrations of Moringa extract solution

	Group	Sum of Squares	df	Mean square	F	Sig.
First Flowering	Between Group	320.00	5	64.00	3.76	.02
	Within Group	306.50	18	17.03		
	Total	625.50	23			

**= 1% level of significance

Appendix VII. Analysis of variance of data on first fruiting of Tomato influence by different concentrations of Moringa extract solution

	Group	Sum of Squares	df	Mean square	F	Sig.
First Fruiting	Between Group	326.83	5	66.37	3.64	.02
	Within Group	323.00	18	17.94		
	Total	649.83	23			

**= 1% level of significance

Appendix VIII. Analysis of variance of data on Fresh weight of Shoot of Tomato as an influence by different concentrations of Moringa extract solution

	Group	Sum of Squares	df	Mean square	F	Sig.
Fresh weight of shoot	Between Group	25150.33	5	5030.07	11.56	.00
	Within Group	7831.00	18	435.06		
	Total	32981.33	23			

**= 1% level of significance

Appendix IX. Analysis of variance of data on Number fruit of Tomato influence by different concentrations of Moringa extract solution

	Group	Sum of Squares	df	Mean square	F	Sig.
Number of Fruit	Between Group	760.87	5	152.18	83.64	.00
	Within Group	32.75	18	1.82		
	Total	793.63	23			

**= 1% level of significance

Appendix X. Analysis of variance of data on Fruit weight per plant of Tomato influence by different concentrations of Moringa extract solution

	Group	Sum of Squares	df	Mean square	F	Sig.
Fruit Weight per Plant	Between Group	1165.19	5	233.04	836.43	.00
	Within Group	5.02	18	0.28		
	Total	1170.21	23			

**= 1% level of significance

Appendix XI. Analysis of variance of data on Yield of Tomato as an influence by different concentrations of Moringa extract solution

	Group	Sum of Squares	df	Mean square	F	Sig.
Yield of Tomato	Between Group	4270992.05	5	854198.41	131.21	.00
	Within Group	117179.19	18	6509.96		
	Total	4388171.25	23			

**= 1% level of significanc

PLATES

Plate 1: Soil Preparation

Plate 2: Pot Preparation

Plate 3: Moringa leaf sorting

Plate 4: Weighing of Moringa leaf

Plate 5: Preparation of Moringa leaf extract

Plate 6: Watering

Plate 7: Data Collection

Plate 8: Experimental field

Plate 9: Tomato fruit in a plant

Plate 10: Weighting of Fruit