EFFECT OF MORINGA LEAF EXTRACT ON GROWTH AND YIELD OF CHILI (*Capsicum annuum L.*)

ASHRAFUL ISLAM

DEPARTMENT OF AGROFORESTRY AND ENVIRONMENTAL SCIENCE
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

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BY

ASHRAFUL ISLAM

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Approved by:

Md. Golam Jilani Helal	**Md. Shariful Islam**
Assistant professor	Associate professor
Supervisor	**Co-Supervisor**

Dr. Nasrin Sultana
Chairman
Examination committee

DEPARTMENT OF AGROFORESTRY AND ENVITONMENTAL SCIENCE

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

CERTIFICATE

This is to certify that the thesis entitled, ***"EFFECT OF MORINGA LEAF EXTRACT ON GROWTH AND YIELD OF CHILI (Capsicum annuum 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* ***ASHRAFUL ISLAM,*** *Registration No. 19-10392 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:
Dhaka, Bangladesh

Md. Golam Jilani Helal
Assistant professor
Supervisor

Dedicated
To
My Beloved Parents

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ABSTRACT

The using of synthetics fertilizers to improve soil fertility and crop yield have adverse effect on soil and environment. Different organic material may use to reduce the use of chemical fertilizers. The main purpose of the study is to evaluate the effect of Moringa leaf extract (MLE) as a growth hormone on growth and yield of chili (*Capsicum annum L.*). The experiment was carried out at Agroforestry and environmental science research field of Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from December, 2021 to May, 2022. This pot experiment was laid out in Randomized block design (RCBD). This experiment comprised of six treatment with seven replications. Treatments were T_0, T_1, T_2, T_3, T_4, T_5 with 0, 15, 30, 45, 60, 75 ml MLE solution respectively. This single factor experiment was done by using chili (BARI Morich-2). The result revealed that different level of Moringa leaf extract showed significant variation on parameters studied during the experiment. The result indicated that T_5 treatment showed highest results on plant height (84.72 cm), leaf number (191.78), number of branches (14.0), stem diameter (2.12 cm), days of first flowering (51.42 days), fresh weight of shoot (364.93 g), fresh weight of root (84.22 g), dry weight of shoot (51.48 g), dry weight of root (15.77 g), number of fruits (194.4), length of fruits (11.17 cm), weight of fruits (311.32 g), yield of fruits (19.60 tha^{-1}). The result also indicated that T_0 treatment showed lowest growth and yield contributing all the parameters. Growth and yield of chili plant gradually increased with the increased of MLE. It can be stated that higher dose of MLE is positively correlated with growth and yield of chili. So, T_5 treatment can recommend to obtain superior growth and yield of chili plant.

LIST OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

LIST OF PLATES

LIST OF ABBREVIATIONS

FULL WORD	Abbreviation	FULL WORD	Abbreviation
Agro-Ecological zone	AEZ	millimeter	ml
And others	*et al.*	Moringa leaf extract	MLE
Bangladesh Agricultural Research Institute	BARI	Nitrogen	N
Bangladesh bureau of statistics	BBS	Number	NO.
Centimeter	Cm	phosphorus	P
Days after transplanting	DAT	Potassium	K
Degree centigrade	^{O}C	Sher-e-Bangla Agricultural University	SAU
Food and Agricultural Organization	FAO	Soil research and development institute	SRDI
Gram	g	Standard Error	SE
hector	ha	Sulphur	S
Kilogram	kg	Ton	t
Meter square	M^2	Ton per hector	Ha/t
milligram	mg	week	wk
		weight	Wt.

CHAPTER 1

INTRODUCTION

Chili (*Capsicum annuum* L.) which belongs to Solananceae family. It is an important spice, which can be consumed fresh as well as processed. It is a good source of vitamins and minerals. The genus Capsicum contains about 20 species and now five domesticated species Capsicum annum, Capsicum frutescens, Capsicum chinense, Capsicum baccatum, Capsicum pubescensare only recognized in Bangladesh. Chilli is widely used as both green and ripe dried form for its pungency. It is the most important vegetable in the world and a condiment but the topmost use of chili throughout the world is as a spice due to its pungency and pleasant flavor (Olaniyi and Ojetayo, 2010).

Chili is one of the valuable medicinal plants in pharmaceutical industry because of its high amounts of antioxidant, capsaicin and capsantin which are the main active substances in it (Aminifard *et al*., 2012). It is also rich in vitamins A and C and contains appreciable quantities of proteins and minerals (Temu and Temu, 2005). In Bangladesh, it is minor vegetable but this crop has got high export potentiality considering its high nutritive value and export potentiality. In Bangladesh the area occupied by chilli cultivation was 239 thousand acres with production of 158 thousand metric ton (BBS, 2020).

Today, most farmers have become aware of the practice organic fertilizer to improve crop production, while also trying to protect the environment (Gopalakrishnan *et al*., 2016). The applications of the extract made from moringa leaves (moringa leaf extract, MLE) is considered as a cheap and environmentally friendly organic fertilizer alternative (Makkar *et al*., 2007).

Moringa oleifera, belonging to the Moringaceae family, is one of 13 species of the genus Moringa, known as the "drumstick tree" (Gopalakrishnan *et al*., 2016), but sometimes also referred to as the "miracle tree", indicating its pharmacological properties. It is a tropical crop grown for its nutritional and medicinal purposes (Foidl *et al*., 2001). Moringa leaves are a good source of highly digestible protein, calcium, iron and vitamins (Yasmeen, 2011). It is considered one of the world's most diversely used trees, as almost every plant part can be used for food, industrial purposes and medication (Khalafalla *et al*., 2010). Plant parts that can be consumed include roots, fruit, leaves and flowers. These plant organs are used as vegetables in Africa, Arabia, India, South Asia, America and Pakistan (Yasmeen, 2011). The young leaves are commonly cooked and eaten like Swiss chard or used to make soups and salads (Fuglie,

2005); they are a good source of vitamin A, the B complex vitamins and vitamin C, as well as of minerals and amino acids, like the essential amino acid leucine and other sulphur-containing amino acids. The green pods are particularly rich in leucine and can be boiled and eaten like green beans (Fuglie, 2005). Recently, *Moringa oleifera* has attracted great attention to enhance plant growth and development, because of its phytochemical components, such as cytokinins, antioxidants, as well as many macro- and micro-nutrients (Abdalla and El-Khashiban, 2012). The leaves are rich in zeatin, a naturally-occurring cytokinin and other growth enhancing compounds like ascorbates, vitamin E, phenolics and minerals (Foidl *et al*., 2001; Nagar *et al*., 2006). Foliar spray of crops with moringa leaf extract (MLE) accelerates plant growth, promotes resistance to stress and increases yield of crops (Price, 1985; Fuglie, 1999; Foidl *et al*., 2001; Fahey, 2005; Marcu, 2005). The frequent and occasional excessive use of chemical inputs have been indicted for adverse effects on the environmental quality because they have potentials to upset the ecological balance of soils and make plants even more susceptible to pests and diseases (Panayotov *et al*., 2010; Fawzy *et al*. 2012).

Studies have proven that plants, such as tomatoes (*Solanum lycopersicum*), plums (*Prunus domestica*), maize (*Zea mays*), chilli (*Capsicum* sp.), Swiss chard (*Beta vulgaris*), cowpeas (*Vigna unguiculata*) and beans (*Phaseolus vulgaris*), displaying an increase in yield following MLE applications. Crops treated with MLE generally also bear larger fruit and have heavier roots and stems (Foidl *et al*., 2001).

The frequent and occasional excessive use of chemical inputs have been indicted for adverse effects on the environmental quality because they have potentials to upset the ecological balance of soils and make plants even more susceptible to pests and diseases (Panayotov *et al*., 2010; Fawzy *et al*. 2012). There is now a growing demand for sound and ecologically compatible and environment friendly techniques in agriculture, capable of providing enough food for the increasing human population; retaining soil quality and improving the quality and quantity of agricultural produce (Russo *et al*. 2012). In view of these, the use of natural growth enhancers has been advocated. Therefore, this work is aimed to investigate the effects of varying concentrations of moringa leaf extract (MLE) on the growth and yield of chili (*Capsicum annuum*) with the following objectives:

Objectives:

1. To evaluate the effect of MLE as a growth hormone on growth and yield of chili.

2. To find out the best dose of moringa leaf extract for chili production.

CHAPTER 2

REVIEW OF LITERATURE

The use of chemical fertilizers to improve soil fertility, and hence, crop yield, have been reported to have adverse effects on agricultural products, man and his environment. Consequence upon this, there is a dire need to evaluate the potentials of certain organic materials to improve soil fertility and crop yield. There is now a growing demand for sound and ecologically compatible and environment friendly techniques in agriculture, capable of providing enough food for the increasing human population; retaining soil quality and improving the quality and quantity of agricultural produce (Russo *et al*. 2012). The organic system provides a better and most nutritious food quality compared to conventional farming (Rembialkowska, 2007). Moringa is considered as a plant that can be a reasonable eco-friendly source of crop yield improvement. The review of literature in terms of "Moringa leaf extract on growth and yield of chilli" mention here with suitable headings:

2.1 Introduction of moringa (*Moringa oleifera*)

The "Moringa" tree is grown mainly in semi-arid, tropical, and subtropical areas. It is native to the sub-Himalayan tracts of India, Pakistan, Bangladesh and Afghanistan (Fahey, 2005). It grows best in dry sandy soil; it tolerates poor soil including coastal areas. It is a fast growing, drought resistant tree. Today it is widely cultivated in Africa, Central and South America, Sri Lanka, India, Mexico, Malaysia, Indonesia and the Philippines. Moringa is a short, slender, deciduous, perennial tree about 10 m tall with drooping branches, brittle stems and branches, corky bark, feathery pale green 30–60 cm long compound leaves, with many small leaflets which are 1.3–2 cm long, 0.6–0.3 cm wide, fragrant white or creamy-white flowers having 2.5 cm in diameter and borne in sprays, pendulous brown triangular pods, splitting lengthwise into 3 parts when dry, containing about 20 dark brown seeds embedded in the pith, pod tapering at both ends. Main root is thick (Foidle et al., 2001). It is considered one of the world's most useful tree, as almost every part of the Moringa tree can be used for food or has some other beneficial property. In the tropics, it is used as forage for livestock, and in many countries moringa micronutrient liquid, a natural anthelmintic (kills parasites) and adjuvant (to aid or enhance another drug) is used as a metabolic conditioner to aid against endemic diseases in developing countries (Foidle et al., 2001).

Moringa oleifera is the most nutrient rich plant yet discovered. Moringa provides a rich and rare combination of nutrients, amino acids, antioxidants, anti-aging and anti-inflammatory properties used for nutrition and healing. *M. oleifera* is a miracle tree with a great indigenous source of highly digestible proteins, Ca, Fe and vitamin C (Fahey, 2005). Some articles and research studies have reported that the dry leaves of *M. oleifera* contain 7 times more vitamin C than orange, 10 times vitamin A than carrot, 17 times calcium than milk, 15 times potassium than bananas, 25 times iron than spinach and 9 times proteins than yogurt (Fuglie, 1999). In addition, it contains vitamin B complex, chromium, copper, magnesium, manganese, phosphorus and zinc (Fuglie, 2000). Thurber and Fahey (2009) stated *M. oleifera* leaves as rich protein source, which can be used by doctors, nutritionists and community health conscious persons to solve worldwide malnutrition or under nutrition problems.

According to researchers moringa has the potential to combat vitamin A and other micronutrient deficiencies (Nambiar, 2006). 40139 μg/100g total carotenoides on fresh weight basis in moringa leaves of which 47.8% or 19210 μg/100g was β-carotene. Ascorbic acid at 6.6 mg/g on dry weight basis, 0.26 mg/g Fe, 22.4 mg/g calcium, 6.3 mg/g P, 11.2 mg/g oxallic acid and 0.9 g/100 g fiber. Moringa has been in use since centuries for nutritional as well medicinal purposes. Another important point is that Moringa leaves contain all of the essential amino acids, which are the building blocks of proteins. It is very rare for a vegetable to contain all of these amino acids. Moringa contains these amino acids in a good proportion, so that they are very useful to our bodies. Given its nutritional value, it can be utilized in fortifying sauces, juices, spices, milk, bread, and most importantly, instant noodles.

2.2 Role of moringa (*Moringa oleifera*) leaf extract (MLE)

A plant growth spray made from moringa leaves increased crop production 20-35%. Spray affects the crops by longer life-span, heavier roots, stems and leaves, produce more fruit, larger fruit and increase in yield 20-35% (Foidle et al., 2001), highlighting its opportunity of use as a foliar spray to accelerate growth of young plants. MLE proved an ideal plant growth enhancer in many experiments (Makkar and Becker 1996; Nouman et al., 2011). Makkar et al. (2007) found the moringa leaves as a source of plant growth factors, antioxidants, βcarotene, vitamin C, and antioxidant agents.

Siddhuraju and Becker (2003) studied the antioxidants properties of moringa leaf extract and demonstrated that it: (1) reduced potassium ferricyanide, (2) scavenged superoxide radicals,

(3) prevented the peroxidation of lipid membrane in liposomes, (4) could donate hydrogen and scavenge radicals.

Cai et al. (2004) observed positive correlation between total phenolic contents and antioxidant activities of methanolic as well as aqueous extracts of Chinese medicinal plants. The aqueous extract obtained from Andrographis paniculata leaves showed more phenolic content and antioxidant potential as compared to extract from other parts such as stem and fruits (Arash et al., 2010). Makkar et al. (2007) found that MLE contains significant quantities of calcium, potassium, and cytokinin in the form of zeatin, antioxidants proteins, ascorbates and phenols. MLE priming in rangeland grass Echinochloa crusgalli showed encouraging results and significantly increased the shoot vigour along with improved number of leaves and fertile tillers (Nouman et al., 2011).

MLE was used as priming agent in hybrid maize. Seed primed with moringa leaf extract (MLE) diluted to 30 times with tap water increased the germination speed and spread and seedling vigor under cool conditions (Noman, 2008). According to Mehboob (2011) high temperature at planting delayed the seedling emergence in control while seed priming treatments resulted in earlier and vigorous seedling stand. Abiotic stresses severely reduced the crop productivity world wide thus these becoming a major threat for food security. Based on physiological and molecular mechanisms of abiotic stress tolerance, various strategies have been advised to improve crop tolerance against abiotic stresses including screening, selection, breeding and genetic engineering etc. However, based on physiological and biochemical bases of stress tolerance in crops, scientists suggested exogenous use of compatible solutes, antioxidants compounds, mineral nutrients, and plant growth regulators as a shotgun approach. Since synthetic compatible osmolytes, antioxidants and plant growth regulators are costly, use of plant extracts having appreciable amount of these compounds could be an economically viable strategy. Among naturally occurring plant growth enhancers, *Moringa oleifera* has attained enormous attention because of having cytokinin, antioxidants, macro and micro nutrients in its leaves.

2.3 Use of moringa as a growth regulator

Plant hormones play an important role in increasing the yield of plants since it influences every stage of plant growth and developments (Maishanu et al., 2017). They are divided into five groups: auxins, gibberellins, abscisic acid, ethylene and cytokinin. Each one is responsible for a specific plant characteristic (Davies, 2010). Plants are producing hormones naturally,

whereas growth regulators or growth enhancers are added to plants artificially by humans. Zeatin is a natural form of cytokine which can be found in a high level (5 µg and 200 µg/g) in fresh moringa leaves. It was mentioned by several researchers (Makkar and Becker, 1996; Basra et al., 2011; Abdalla, 2013; Unuigbe et al., 2015) that due to having zeatin in the moringa leaves, which is an effective plant growth hormone, many crop yields as soybean, maize and coffee can be improved by 25-30% using moringa juice extract.

Weerasingha and Harris (2020) reported that MLE is considered as a natural plant growth enhancer. Because it contains appreciable amounts of plant growth regulators such as cytokinin in the form of zeatin, antioxidants, proteins, β-carotene, vitamin C and phenols, and had a remarkable effect on yield in many plants such as onions, bell pepper, soybean, sorghum, coffee, tea, chilli, melon and maize.

Moringa leaf extract is used as an effective plant growth hormone to enhance seed germination, improving yield and growth in plants (Edward and Jenny, 2009; Phiri, 2010). Similar results were stated for the foliar spray with moringa leaf extract (6 g/L) and some other hormones as cytokines as benzyladenine or ascorbic acid (100 ppm) on growth and yield of Squash (Hegazi et al., 2015). Because of having antioxidant compounds like zeatin, ascorbic acid, phenolic, flavonoids, vitamin E and minerals in moringa leaves, it can be used to enhance the metabolism of plants and overcoming plants from environmental stress (Isman, 1997; Latif and Mohamed, 2016).

Moringa leaf extract (MLE) is used as a plant growth enhancer which is obtained from young leaves in (80% ethanol) then spraying on the plant leaves (Abd El-Hack et al., 2018). Except for trace elements, biochemicals and minerals, the extract contains many other growth hormones such as indole3-acetic acid (IAA) and gibberellins (GAs), so that it is strongly suggested to use MLE as a natural plant bio-stimulants to improve yield and growth of plants (Rady and Mohamed, 2015).

Manzoor et al. (2015) reported that the concentration of 5% leaf extracts (MLE) and root extracts (MRE) significantly increased growth and reduced aphid infestation in wheat crop, as well as improved leaf area index, total dry matter, growth rate, spike numbers, and the total yield. Moringa leaf extract is also used as a growth promoter in seed germination of many cereal crops like sorghum, rice, wheat and maize (Chattha *et al.*, 2018).

2.4 Common uses of moringa leaf extract in vegetable production

Moringa leaf extract has been treated in the form of foliar spray for many reasons such as plant growth regulator to increase drought tolerances, germination and early seedling development against saline stress by different plants, for instance, maize (Biswas et al., 2016), wheat (Yasmeen et al., 2013), different cereals-maize, rice, sorghum and wheat (Phiri, 2010), beans (Rady and Mohamed, 2015).

Chang *et al.* (2007) have found that plants sprayed with moringa leaf extract lead to have more vigour growth and improve the ability of vegetables to combat with different environmental conditions. All the results show the positive effect of the moringa leaf extracts on the treated crops. However, there is rather limited research on the effect of moringa leaf extracts on vegetables. It is mostly used in vegetable production as a growth regulator, eco-friendly bio-pesticide, and mineral supplement (Abd El-Hack et al., 2018).

Culver et al. (2012) presented that moringa leaf extract increased dry matter, plant weight, and the total yield of tomatoes. Growth and yield of pepper can be increased with the spray of moringa leaf extract at the concentration of 5% (Matthew, 2016).

El-Saady and Omar, (2017) have stated in their experiment that the best result of head lettuce (cv. Big Bell) recorded in the treatment of the interaction of 5 cm^3/l adding microorganisms and foliar spraying of MLE three or two times. Physical quality rocket (*Eruca vesicaria* subsp. sativa) and its some bioactive compounds are improved in the foliar spray with 2-3 % of MLE (Abdalla, 2013). The significantly highest protein content and fresh pod 82.5% and 45%, respectively, was obtained in pea plants (*Pisum sativum* L.) sprayed with 4% of moringa leaf extract (Merwad, 2018).

All the experiments demonstrate that moringa leaf extracts increase the growth and yield of different plants. This effect was stated by the following crops-onions, bell pepper, soybeans, sorghum, coffee, tea, melon and maize (Fuglie, 2000). Hacisevki (2009) reported that moringa leaf extract also increased the resistance against pests and diseases, furthermore producing larger fruits and higher yield by 20 to 35 %. It also reduces drought stresses in squash plants in the experiment with spraying 3% MLE (El-Mageed et al., 2017).

Moringa can be considered as an alternative to inorganic fertilizer and it can improve not only the yield but also enhancing germination seeds mostly field crops (Phiri, 2010). Physical and quality parameters of sweet pepper was significantly greater in the plants treated with 80 g/L

of moringa leaf powder (Sowley et al., 2014). The juice also has a character as antifungal disorder which is used as a proper agent for treating seeds instead of using chemicals to inhibit the attack of seed born fungal pathogens (Akinbode and Ikotun, 2008).

Beans, cowpea and groundnut treated with moringa leaf extract increased germination percentage by 4%, radical length by 4% and hypocotyl length by 16.6% respectively (Phiri and Mbewe, 2010). Based on the research by Abusuwar and Abohassan (2017) forage cereals such as Sorghum, Pearl millet, and Rice have improved growth and productivity while treated with moringa leaf extract under salt stress and aired conditions.

2.4.1 Effect of moringa on growth and yield of chilli

Weerasingha and Harris (2022) carried out a pot experiment during the period from January to May 2019 to ascertain the effect of foliar application of moringa leaf extract (MLE) on growth and fruit yield of *Capsicum annum* L.cv (chilli) MIPC-1. The concentrations of Moringa leaf extract were 10%, 20%, 30% in addition to 0% (distilled water) as control. The treatments included were; T0 - control (Distilled water), T_1 - 10% MLE at once a week interval, T_2 - 10% MLE at once in two weeks interval, T_3 - 20% MLE at once a week interval, T_4 - 20% MLE at once in two weeks interval, T_5 - 30% MLE at once a week interval and T_6 - 30% MLE at once in two weeks interval. The *Moringa oleifera* leaf extract was sprayed on leaves and axial parts starting from two weeks after transplanting (WAT) and it was continued until pod formation. 25 ml of MLE was sprayed per plant. The results of the experiment showed that the foliar application of MLE with 10% concentration at one-week interval had significant ($p<0.05$) effects on the plant height, number of branches/plant, dry weight of leaves/plant, stems/plant, roots/plant, fruit/plant and total dry of plant. The results indicated that the foliar application of moringa leaf extract stimulated the growth and fruit yield of chilli. Based on the results, it was concluded that MLE helps in improving the growth and fruit yield of Chilli and MLE with 10% concentration at one- week interval is recommended for improved growth and fruit yield of *Capsicum annuum* L.cv. (Chilli) MIPC-1.

Woke and Ansa (2020) carried out a pot experiment to evaluate the effect of rates of moringa leaf extract on growth and fruit quality of bell pepper *Capsicum annuum*. The treatment were rates or concentrations of the moringa leaf extract (0%, 4%, 8% and 12%) applied to soil filled poly bags, arranged in a randomized complete block design replicated three times and using replicates as blocks. The parameters evaluated were plant height, Fruit fresh weight, Fruit dry weight, Proximate analysis, Lycopene and Vitamin A contents. The results show that fresh and

dry weight of the bell pepper increased as moringa leaf extract increased. While moisture content increased with decreasing levels of moringa leaf extract, protein, fats, carbohydrate, ash, lycopene, vitamin A and vitamin C contents increased with increasing levels of moringa leaf extract. 12% concentration recorded the highest value in all parameters evaluated. Application of 12% concentration of moringa extracted is recommended.

Stohs and Hartman (2020) conducted a pot experiment from December to May 2018 to evaluate the impact of *Moringa oleifera* leaf extract (MLE) on yield and quality attributes of chilli (*Capsicum annuum* L.) var. MIPC-01. The treatments were (T0) control (Distilled water), T1, T3 and T5 - 15, 30 and 45% MLE application was in once a week whereas T2, T4 and T6 - 15, 30 and 45% MLE application was once in two weeks interval. Young moringa leaves and the tender parts were shade dried for four days and made into powder. Then the powdered material was used for the preparation of MLE. Stock solution (100% MLE) was prepared and refrigerated and then, the different concentrations were prepared by adding distilled water on volume basis. Foliar application of MLE was commenced at 2 weeks after transplanting (WAT) and continued until pod formation. For once in a week and once in two weeks, the plants were sprayed with MLE eight and four times respectively. At each time, the plant was sprayed with 25 ml of MLE. The results suggest that foliar application of MLE at 15% in one week interval had significant ($p<0.05$) effects on the number of pods/ plant, number of seeds/pod, length of the pod, total yield/plant, leaf chlorophyll content, total soluble solid content over the control. Therefore, it was concluded that MLE is helpful in improving yield and quality attributes of chilli and MLE at 15% at one week interval is recommended for improving the yield and quality of chilli. Application of MLE is the cheapest, environmental friendly and low-cost technology for enhancing yield in chilli.

Onyegbule *et al*. (2018) conducted a study and evaluated the influence of Moringa leaf extract (MLE) and spraying regime on the growth and yield of sweet pepper. Three rates of MLE (0, 50% and 100% concentration) and three spraying regimes (no spray, weekly spray, bi-weekly spray) were utilized. Data were collected at 4,6,8 and 10 weeks after transplanting (WAT) on plant height (cm), number of leaves, canopy spread (cm), stem girth (cm), fruit number/plot, fruit weight (t/ha), fruit length (cm) as well as fruit diameter(cm). Results indicated that the Moringa leaf extract significantly ($p<0.05$) increased the growth and yield parameters measured relative to the control. . MLE application gave highest plant height of 79.3 cm at 10 WAT, while weekly spray recorded highest plant height of 78.1 cm also at 10 WAT. Weekly spray at 10 WAT showed higher stem girth of 1.6 cm although, this value was not significantly

($p>0.05$) different from the value (1.5 cm) obtained from the bi-weekly application. The interaction of MLE and spraying regime on plant height was not significant ($p>0.05$).The MLE increased the number of fruits, fruit weight, fruit length and fruit diameter relative to the control. Highest values on number of fruits (72), fruit weight (1.96 t/ha), fruit length (3.4 cm) and fruit diameter (2.48 cm) was obtained at 100 % concentration rate of application which was significantly ($p<0.05$) different from the control. Also, weekly spray gave better yield increases in number of fruits (78), fruit weight (1.48 t/ha) and fruit length (3.7 cm) although these values were not statistically different from that obtained from bi-weekly spray. The interaction effects of MLE and spraying regime on fruit weight, fruit length and fruit diameter was not significant.

Hala *et al*. (2017) carried out a study during the two summer seasons of 2014 and 2015 on pepper (*Capsicum annuum* L.) cv. California Wonder. The goals of this investigation were enhancing either the speed of pepper seeds germination or its percentage, produce healthy seedlings, vigour growth and improve fruit yield and its quality by using moringa leaf extract (MLE). The concentrations used of MLE extract were 2% - 4% - 6% in addition to 0% (tap water) as control. The moringa extract was added through two methods i.e., seed soaking treatment for 3 and 6 hours before planting the nursery and as plant foliar spray either on the seedlings during nursery stage or after transplanting in the open field . The obtained results indicated that moringa leaf extract at 4% concentration as seed soaking for 6 hours stimulated germination percentage, rate, index as well as coefficient of germination velocity. Moreover, the same concentration (4%) of MLE as a foliar spray on pepper seedlings in the nursery was sufficient to support all seedlings parameters expressed as height, fresh and dray weight, number of leaves and leaf area. Moreover, the maximum plant growth parameters as well as superior early and total fruit yield were obtained from the same treatment. Furthermore, MLE at concentration of 4% increased average fruit weight, length and diameter as well as fruit chemical contents such as carbohydrate, ascorbic acid and both of K and Ca elements.

Dunsin and Odeghe (2015) carried out an experiment for evaluating the response of sweet bell pepper to Moringa Leaf Extract (MLE) and Organo Bio Degradable fertilizer (OBD^{+}). The treatments included four levels of Organo-Bio Degradable fertilizer (0g, 20g, 40g and 60g) Moringa Leaf Extract at ratio 1:32 (v/v) was sprayed directly at the plant at 1 and 2 weeks after transplanting respectively and replicated thrice in a Completely Randomized Design (CRD). The results showed that plant height, number of leaves, fruit weight and yield of sweet bell

pepper were significantly ($P \leq 0.05$) influenced by the application of Moringa Leaf Extract and Organo-Bio Degradable fertilizer (OBD^{+}).

2.4.2 Effect of moringa on growth and yield of other crops

Jan *et al*. (2022) carried out a field experiment entitled "Exogenous application of Moringa leaves extract influences growth, flowering and vase life of snapdragon cultivars". The experiment was laid out in Randomized Complete Block Design with a factorial arrangement having two factors i.e. Cultivars (Potomac and Rocket) and Moringa leaf Extract (MLE) concentrations (0%, 10%, 20%, 30%) replicated three times. Cultivars and MLE concentrations significantly affected the studied parameters. Statistical analysis showed that Rocket cultivar produced maximum numbers of leaves plant-1 (126.50), stem diameter (11mm), plant height (100cm), number of florets spike-1 (34), flowering duration (39days) and vase life (6days) as compared to Potomac cultivar. Similarly, most number of leaves plant-1 (114), stem diameter (11mm), plant height (99cm), number of florets spike-1 (35), flowering duration (44 days), and vase life (8days) was recorded in plants treated with 30% MLE extract. It is concluded that 30% MLE for exogenous application and Rocket cultivar for commercial production is recommended in agro-climatic conditions of Peshawar valley.

Hoque *et al*. (2022) conducted a field study to evaluate the influence of MLE (Moringa Leaf Extract) on the growth, yield and nutritional improvement in two vegetable crops [Tomato (*Solanum lycopersicum*) and Indian Spinach (*Basella alba*)]. The extract was applied at two weeks interval with different frequencies. The crops were fertilized with chemical fertilizers and MLE application was done as per treatment @ 25 ml/plant. For each of the crops, this bio-stimulant had a significant boosting effect on growth, yield and nutrient uptake whereas the maximum frequency in the application i.e. T_4 (foliar application of MLE at 2 weeks after transplanting and application at every 2 weeks thereafter) showed the highest influence. Indian Spinach responded proportionally more to foliar-applied MLE in terms of plant growth and nutrient uptake compared to tomato. The effect of MLE on the yield parameters was more pronounced in tomato that showed a 25% (averaged across all the growth parameters) increase over control, but Indian Spinach showed >20% increase in yield parameters compared to control.

Yaseen and Hajos (2020) reported that *Moringa oleifera* is the most nutritious tree that has ever been found. Almost all parts of the plant can be used as an eco-friendly nutrient supplement and natural bio-pesticide to improve crop growth and yields. Based in this fact this review

article aims to focus on the possible role of *Moringa oleifera* as an alternative source of the environmentally friendly product in organic vegetable production. It is evident that the plant is rich in antioxidants, antibiotics, nutrients, including vitamins and minerals, protein, and carotenoids. Due to the presence of high concentration of different hormones mainly zeatin, it can be used to improve the yield of many types of crops by 10-45 per cent apart from the lowest cost of production. Many research papers demonstrate the benefits of the tree in different aspects like livestock production, medicine, manufacturing, water purification, source of nutrients in poor nations, and food technology.

Ahmed *et al*. (2020) conducted a greenhouse study to evaluate the growth and yield of cucumber (*Cucumis sativus* L.) F1 hybrid cv. 'Hesham' in response to foliar application with three concentrations (1:40, 1:30 and 1:20) of moringa leaf extract. Cucumber growth traits (plant height, leaf area, number of leaves, fresh and dry weight of leaves and stems) and flowering traits (number of flowers, number of days to the first female flower and fruit set %) were significantly enhanced following the foliar application with moringa leaf extract. The growth and development of cucumber fruits (fruit fresh and dry weight, and fruits total yield) were also promoted in response to the treatments. Moringa leaf extract treatments markedly increased the endogenous hormone levels (auxins, gibberellins and cytokinins) and enhanced the activity of the antioxidant enzymes catalase, peroxidase and superoxide dismutase in cucumber leaves. This stimulation effect revealed that moringa leaf extract might be utilized as an effective natural and safe biostimulant in organic agricultural production.

Kanchani and Harris (2019) carried out a field experiment to study the effects of different concentrations and frequencies of Moringa (*Moringa oleifera*) Leaf Extract (MLE) as a foliar application on growth and yield of okra (*Abelmoschus esculentus*) plants. This experiment consisted of the following treatments; T0 - control (Distilled water), T1 - 10% MLE at once a week interval, T2 - 10% MLE at once in two weeks interval, T3 - 20% MLE at once a week interval, T4 - 20% MLE at once in two weeks interval, T5 - 30% MLE at once a week interval and T_6 - 30% MLE at once in two weeks interval. Foliar application of MLE was initiated at two weeks after germination and each plant is sprayed with 25 ml of MLE and the growth performance was recorded at 4, 6 and 7 WAP. The results showed that foliar application of MLE had a significant ($p<0.05$) effects on tested parameters of okra over the control at all growth stages. MLE with 10% of the foliar application at once a week interval increased plant height, number of branches/plant, number of leaves/plant, leaf area index, dry weight of leaves, stems, roots, total biomass, number of pods/ha and dry weight of pods. The results suggest that

under the conditions in the experiment, yield could be increased by three-fold using MLE at 10%. The use of Moringa leaf extract as a plant growth booster is inexpensive, environmentally safe and low-cost technology to improve the yields by the small farmers.

Ullah *et al*. (2019) carried out an experiment to study the influence of moringa leaf extracts (MLE) and humic acid (HA) foliar application on growth, yield and physico-chemical components of cucumber. Different levels of MLE (control, 30, 40 and 50 gL^{-1}) and HA concentrations (Control, 0.5, 1 and 1.5%) were applied for foliar application. Data were recorded on various yield and quality attributes. Statistical analysis showed that MLE and HA affected almost all the studied attributes, while the interaction was found non-significant. Results indicated that foliar application of MLE at the rate of 50 gL11 gave maximum vine length (164.75 cm), single fruit weight (172.25 g), fruit diameter (4.31 cm), total yield (40.93 tons ha-1), TSS (2.91 0Brix), titratable acidity (0.49%) and ascorbic acid content (5.79 mg 100g-1) with minimum days to first harvest (54.08) and fruit juice pH (5.36). whereas HA concentration, 1.5% showed best performance in all the studied attributes as compared to other treatments. Maximum vine length (166.08 cm), single fruit weight (171.50 g), fruit diameter (4.37 cm), total yield (41.84 tons ha-1), TSS (2.83 0Brix), titratable acidity (0.48%), and ascorbic acid (6.00 mg 100g-1) with minimum days to first harvest (54.00) and fruit juice pH (5.27) were recorded using HA at the rate of 1.5%. It was concluded that 50 gL-1 MLE improved yield and chemical composition of cucumber, while 1.5% HA also showed best results.

El-Sayed *et al*. (2018) conducted Two main field trials to study the potential effects of moringa seed (MSE; 0.5%) extraction growth and yield, physio-biochemical components, antioxidant defense system, and contamination of pepper plants grown on heavy metals-contaminated saline soil. MSE was applied in two single treatments (i.e., with drip irrigation water; SA or as foliar spray; FS) or in integrative (i.e., MSESA + MSE-FS) treatment. The results showed that all single or integrative treatments significantly increased plant growth and yield, leaf contents of leaf photosynthetic pigments, free proline, total soluble sugars, N, P, and K+, ratio of K+/Na+, and activities of CAT, POX, APX, SOD and GR, while significantly reduced contaminants; Na+, Cd, Cu, Pb and Ni contents in plant leaves and fruits compared to the control (free from MSE). Additionally, the integrative MSE-SA + MSE-FS treatment significantly exceeded all single treatments in this concern. The integrative MSE-SA + MSE-FS treatment was the best that it had been recommended for maximizing pepper fruits with minimizing contaminants on heavy metal-contaminated saline soils.

Jhilik *et al*. (2017) conducted an experiment to evaluate the effect of foliar application of moringa leaf extract on growth and yield of late sown wheat (BARI Gom-26). The treatments were T_1 (Control), T_2 [moringa leaf extract (MLE) sprayed only at tillering stage], T_3 (MLE sprayed at tillering and jointing stages), T_4 (MLE sprayed at tillering, jointing and booting stages), T_5 (MLE sprayed at tillering, jointing, booting and heading stages), and T_6 (MLE sprayed only at heading stage). Application of moringa leaf extract significantly increased the growth and yield attributes as well as grain and straw yield of wheat. Among various treatments with moringa leaf extract the performance of T_4 (MLE sprayed at tillering, jointing and booting stages) was the best as it produced the tallest plant (87.87 cm), the highest fresh and dry weight of root (16.51 g and 11.37 g respectively), the highest number of spikelets spike-1 (19.70) and filled grains spike-1 (45.53), as well as the highest grain and straw yield (3.62 t ha-1 and 5.43 t ha-1 respectively) of wheat. Therefore, moringa leaf extract as a foliar spray can be applied at critical growth stages to increase the growth and yield potentiality of late sown wheat.

CHAPTER 3

MATERIALS AND METHOD

The study was conducted during the period from December 2021 to May 2022 to the study the effect of moringa leaf extract on the growth and yield of chilli (*capsicum annum*). The materials and methods describes a short description of the experimental site, climate, collection of material, treatment of design, preparation of Moringa leaf extract, collection of seedling, data collection procedure and data analysis. The experiment was conducted at single phase growth and yield in pot. The detailed materials and methods that were used to conduct the study are presented below under the following headings

3.1 Study location:

The experiment was conducted at Agroforestry and Environmental Science research field of Sher-e-Bangla agricultural university, Sher-e-Bangla Nagar, Dhaka. The location of the experiment site was at 23°75′ N latitude and 90°34′ E longitude with an elevation of 8.45 meter from sea level (Appendix I)

3.2 climate

The experiment site was situated in subtropic climate zone, characterized by heavy rainfall during the months from April to September (kharif season) and scanty rainfall during the rest of the year (Rabi season). The soil of the experiment was collected from Agroforestry and Environmental research field which was sandy loam. There was less rainfall during the experiment period. Rabi season was characterized by plenty of sunshine.

3.3 Soil Characteristics

The research work carried out in a high land belonging to the AEZ 28, Madhupur tract (Tejgaon soil series). The structure of the soil was fine with and 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 (FAO, 1998).

3.4 Collection of materials

Experiment was done by using chili (BARI Morich-2) which was collected from Horticulture research field, Sher-e-Bangla Agriculture University. For preparing stock solution *moringa olifera* leaf was collected from Agroforestry and Environmental science research field, Sher-e-Bangla Agricultural University.

3.5 Treatments of the experiment

The single factor experiment was conducted in pot. The experiment was conducted following randomized complete block design (RCBD) with seven replications. Five Treatments were used in this experiment with one control. Total combination of treatments and replications were 42. Treatments were

T_0: 0 ml (control)

T_1: Moringa leaf extract sprayed at 15 ml

T_2: Moringa leaf extract sprayed at 30 ml

T_3: Moringa leaf extract sprayed at 45 ml

T_4: Moringa leaf extract sprayed at 60 ml

T_5: Moringa leaf extract sprayed at 75 ml

3.6 Lay out of Experimental plot

R_1T_3	R_1T_2	R_1T_5	R_1T_0	R_1T_1	R_1T_4
R_2T_4	R_2T_5	R_2T_1	R_2T_3	R_2T_0	R_2T_2
R_3T_3	R_3T_2	R_3T_0	R_3T_5	R_3T_1	R_3T_4
R_4T_2	R_4T_5	R_4T_0	R_4T_4	R_4T_3	R_4T_1
R_5T_3	R_5T_1	R_5T_4	R_5T_2	R_5T_0	R_5T_5
R_6T_4	R_6T_2	R_6T_1	R_6T_5	R_6T_3	R_6T_0
R_7T_2	R_7T_3	R_7T_5	R_7T_1	R_7T_0	R_7T_4

3.7 Pot preparation:

Top soil was collected from experimental field and then pulverized. The inert materials visible insects pests and weeds were removed. Then the soil was dried thoroughly. Cow dung, urea, TSP per pot were incorporated uniformly into the soil. Clean and dried plastic pot of 12kg size were used for experiment. Each pot was filled with 10 kg previously prepared soil.

3.8 Preparation of moringa leaf extract and treatment procedure

500gm moringa leaves were collected from *moringa olifera* tree. Mature leaves were collected from tree. The leaves were grinded with the help of blender by mixing 500ml water. For each treatment 15ml Moringa leaf extract was mixed with 60ml of 80% aqueous Ethanol and this

mixer were diluted in distilled water at ratio 1:20. Total 1575ml mixer were required for each time treatment. Moringa leaf extract were added to the pot at the rate of 0ml (control), 15ml, 30ml, 45ml, 60ml, 75ml in one week interval.

3.9 Collection of seedling:

Seedling of chili (BARI Morich-2) were raised on a nursery bed at Horticulture Research field of SAU. Two seedlings transplanted to each pot two weeks after emergence. The seedlings were later thinned to one seedling per pot a week after of transplant.

3.10 Management Practice

3.1o.1 Fertilizer Application

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

3.10.2 Weeding and Irrigation

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

3.10.3 Pest and Disease Management

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

3.11 Data collection

The following data on growth and yield of chili were collected

1. Plant height (cm)
2. Number of leaves per plant
3. Number of branches
4. Diameter of plant (cm)
5. days of first flowering

6. Fresh weight of shoot (g)

7. Fresh weight of root (g)

8. Dry weight of shoot (g)

9. Dry weight of root (g)

10. No. of fruits

11. Length of fruits (cm)

12. Weight of fruits (gm)

13. Yield of fruits (t/ha)

3.11.1 Plant height

Plant height was recorded from two weeks later after transplanted. Plant height was recorded 15 days interval. Height was recorded by scale. Plant height was measured from base to the tip of the plant.

3.11.2 No. of leaves

Number of leaves of each plant was counted at vegetative and fruiting stage. NO. of leaves was recorded 15 days interval. All the leaves of each plant was counted separately. Only the smallest young leaves at the growing point of the plant were excluded from counting. The average number of leaves of seven replications gave the number of leaves for per treatment.

3.11.3 No. of branches

Number of branches of each plant was counted at vegetative and fruiting stage. No. of branches was recorded 15 days interval. Only the smallest young branches at the growing point of the plant were excluded from counting. The average number of branches of seven replications gave the number of branches for per treatment.

3.11.4 Diameter of plant

Diameter of each plant was counted at vegetative and fruiting stage. Diameter of plant was recorded 15 days interval. Diameter was counted by using slide calipers. Diameter was counted

above base level. The average diameter of plant of seven replications gave the number of diameter for per treatment.

3.11.5 days of first flowering

Days of first flowering were counted in the interval between transplating to first flowering. The average number of days first flowering seven replications gave the number of days of first flowering for per treatment.

3.11.6 Fresh weight of shoot (g):

After harvesting, shoots were separated from root in every plant. Then shoots weight were weighted separately by balance. The sum of the fresh weight of seven plants were divided by seven. Then it was recorded as fresh weight of per treatment. Fresh weight of shoot was expressed in gram (g).

3.11.7 Dry weight of shoot (g):

After harvesting, selected plants shoots were put into paper packet and placed in roof and dried in sun dry for seven days. The sample were transferred in room and then final weight of the sample was taken. Average weight was measured in gram (g) and expressed as dry weight per treatment.

3.11.8 Fresh weight of root (g):

After harvesting, shoot were separated from root in every plant. Then roots weight were weighted separately by balance. The sum of the fresh weight of seven plants were divided by seven. Then it was recorded as fresh weight of per treatment. Fresh weight of root was expressed in gram (g).

3.11.9 Dry weight of root (g):

After harvesting, selected plants root were put into paper packet and placed in roof and dried in sun dry for seven days. The sample were transferred in room and then final weight of the sample was taken. Average weight was measured in gram (g) and expressed as dry weight of root per treatment.

3.11.10 No. of fruits

Number of fruits of each plant was counted after harvesting. The average number fruits of seven replications gave the number of fruits for per treatment.

3.11.11 Length of fruits (cm)

Length of three fruits from each treatment were recorded by scale. Average fruits length gives length of fruits per plant.

3.11.12 Weight of fruits

Weight of fruits of each plant was counted after harvesting. The weight of the fruits were calculated by using digital balance. The average weight of fruits of seven replications gave the weight of fruits for per treatment.

3.11.13. Fruit yield t/ha

It was measured by following formula,

$$\text{Fruit yield (t/ha)} = \frac{\text{yield of fruits per pot (kg)} \times 42000}{1000}$$

3.12 Statistical analysis

The data obtained for different parameter were statistically analyzed to observe the significant difference among the treatment. The mean value of all the parameters was calculated and analysis of variance was performed. The recorded data on different parameters were statistically analyzed by using SPSS version 16 software to find out the significance of variation resulting from the experimental treatment. The mean values for all the treatments were accomplished by Duncan test. The significance of difference between pair of means was tested at 5% and 1% level of probability.

CHAPTER 4

RESULTS AND DISCUSSION

In this experiment, efforts were made to find out the effect of Moringa leaf extract on growth and yield of *Capsicum annum* L. Data on different parameters were analyzed statistically. The results have been presented and discussed in this chapter with the following headings and sub-headings.

4.1 Growth parameters

4.1.1 Plant height

Different doses of Moringa leaf extract (MLE) showed significant variation on plant height of chili at different days after transplanting (Table 1). The plant height was increased gradually with the increase of Moringa leaf extract. The highest plant height was found from T_5 treatment at all the growth stages (8.27, 13.55, 22.21, 44.51, 64.31, 84.72cm at 15, 30, 45, 60, 75, 90 DAT respectively). The lowest plant height was observed from T_0 treatment (8.50, 12.34, 21.60, 34.02, 54.07cm at 30, 45, 60, 75, 90 DAT respectively) except 15 DAT. At 90 DAT, T_5 exhibited the highest plant height (84.72cm) which was significantly different from the plant height recorded in T_0, T_1, T_2, T_3, T_4, and T_5 treatments where the lowest Chili plant height (6.48 cm) was found from T_1 treatment. The result on plant height obtained from present study revealed that high amount of moringa leaf extract increase the plant height. MLE extract is rich and significant in phyto-hormones like indole-3-acetic acid (IAA), gibberellins (GAs), and zeatin as a cytokinin. It also includes micro and macro necessary nutrients. The MLE's varied composition suggests that it can be employed as a plant bio-stimulant. Fugle (2000) reported that MLE accelerate the growth of young plant. More moringa leaf extract provides more growth hormones. Plant height is more in T_5 because sprayed MLE in high amount. A similar result also found by Aluko Matthew (2016)

Table 1. Effect of Moringa leaf extract on plant height of Chili

Treatment	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
T_0	8.26 b	8.50 d	12.34 e	21.60 d	34.02 e	54.07 e
T_1	6.48 b	9.63 d	15.67 d	32.38 c	44.14 d	62.91 d
T_2	7.38 a	10.97 c	18.78 c	37.52 bc	50.81 c	69.04 c
T_3	7.45 a	11.41 bc	20.04 bc	39.60 ab	54.35 bc	73.40 c
T_4	7.75 a	12.48 ab	21.31 ab	42.95 ab	58.40 b	78.65 b
T_5	8.27 a	13.55 a	22.21 a	44.51 a	64.31 a	84.72 a
Level of significance	**	**	**	*	*	*
SE(±)	0.17	0.31	0.61	1.42	1.68	1.03

*=significant at 5% levels of significance **=significant at 1% levels of significance
T_0: 0 ml (control), T_1: Moringa leaf extract sprayed at 15 ml, T_2: Moringa leaf extract sprayed at 30 ml, T_3: Moringa leaf extract sprayed at 45 ml, T_4: Moringa leaf extract sprayed at 60 ml, T_5: Moringa leaf extract sprayed at 75 ml

4.1.2 Number of leaf

Number of leaves in plant showed significant variation among the treatments at different DAT (Figure 1). Plants which are treated with T_5 treatment showed highest number of leaves at all the growth stages (8, 32.57, 55.43, 99.71, 1234.43 and 191.71 at 15, 30, 45, 60, 75, 90 DAT respectively). The plants which are not treated with any moringa leaf extract (MLE) showed lowest number of leaves all the stages (4.86, 14.56, 25.71, 56.57, 76.86, 126.86 at 15, 30, 45, 60, 75, 90 DAT respectively). At 90 DAT, T_5 exhibited the highest number of leaves (191.71) which was statistically different from the number of leaves recorded in T_0, T_1, T_2, T_3, T_4, and T_5 treatments where the lowest Chili plants leaves number (4.86) was found from T_0 treatment. Chili plant leaves number significantly increased with the increase of MLE.

This result indicated that moringa leaf extract (MLE) helps to increase plant leaves. Different plant growth hormones which were presented in moringa leaf favors to increased number of leaves of chili plant. This result was supported by the finding of Aluko Matthew (2016)

Table 2. Effect of Moringa leaf extract on number of leaf of chili

Treatment	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
T_0	4.86 c	14.57 f	25.71 f	56.57 f	76.86 f	126.86 f
T_1	6.00 b	19.14 e	33.71 e	68.00 e	89.43 e	148.00 e
T_2	7.43 a	23.14 d	42.57 d	80.29 d	100.29 d	162.86 d
T_3	7.71 a	26.57 c	47.43 c	87.71 c	108.86 c	172.00 c
T_4	8.00 a	29.71 b	50.86 b	93.43 b	116.00 b	180.57 b
T_5	8.00 a	32.57 a	55.43 a	99.71 a	123.43 a	191.71 a
Level of significance	**	**	**	**	**	**
SE(±)	0.23	1.00	1.65	2.38	2.54	3.38

4.1.3 Number of branches

Due to the application of various amounts of Moringa leaf extract, significant variations in chili plant branches were found (Table 2). As crop development progressed until the final harvest, the number of branches of plant progressively grew. Plants which are treated with T_5 treatment showed highest number of branches at all the growth stages (6.57, 8.85, 10.85, 13, and 14.0 at 30, 45, 60, 75, 90 DAT respectively). The plants which are not treated with any moringa leaf extract (MLE) showed lowest number of branches all the stages (2.57, 4.28, 6.14, 8.28, 10.42 at 30, 45, 60, 75, 90 DAT respectively). The lowest Chili plant branches (2.57) was discovered from T_0 treatment, while T_5 showed the greatest plant number of branches (14) at 90 DAT, which was significantly different from the plant height recorded in T_0, T_1, T_2, T_3, T_4, and T_5 treatments. The number of chili leaves increased significantly with increasing MLE.

This result indicated that different level of moringa leaf extract (MLE) helped to increase plant branches. This might be caused due to present of different growth hormones in MLE. Moringa leaf extract (MLE) contains different growth hormones like Zeatin which is a naturally form in fresh moringa leaves. Fuglie (2000) found that high concentration of MLE increased vegetative growth that support this result.

Table 3. Effect of Moringa leaf extract on number of branches of Chili

Treatment	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
T_0	2.57 d	4.28 d	6.14 e	8.28 e	10.42 e
T_1	3.57 cd	5.14 cd	7.00 de	9.28 d	11.42 d
T_2	4.14 c	6.00 c	7.42 cd	10.00 cd	12.00 c
T_3	4.57 bc	6.28 bc	8.14 c	10.71 c	12.42 c
T_4	5.57 ab	7.42 b	9.42 b	11.71 b	13.14 b
T_5	6.57 a	8.85 a	10.85 a	13.00 a	14.00 a
Level of significance	**	**	**	**	**
SE(±)	.26	.29	.28	.26	.19

*=significant at 5% levels of significance **=significant at 1% levels of significance
T_0: 0 ml (control), T_1: Moringa leaf extract sprayed at 15 ml, T_2: Moringa leaf extract sprayed at 30 ml, T_3: Moringa leaf extract sprayed at 45 ml, T_4: Moringa leaf extract sprayed at 60 ml, T_5: Moringa leaf extract sprayed at 75 ml

4.1.4 Stem diameter

The stem diameter of chili at various days following transplanting varied significantly depending on the amount of moringa leaf extract (MLE) (Figure 2). As the amount of moringa leaf extract rose, the plant stem diameter steadily increased. Highest stem diameter was found from T_5 treatment at all the growth stage (.61, 1.03, 1.47, 1.93, 2.12cm at 30, 45, 60, 75, 60 DAT respectively). The lowest stem diameter was observed from T_0 treatment (.41, .70, .96, 1.37, 1.68cm at 30, 45, 60, 75, 90 DAT respectively). The lowest stem diameter (.41cm) was discovered from T_0 treatment, while T_5 showed the greatest stem diameter (14) at 90 DAT, which was statistically different from the stem diameter recorded in T_0, T_1, T_2, T_3, T_4, and T_5 treatments.

The bigger plant at highest doses received more growth hormone and nutrients that might encouraged more vegetative growth.

Table 4. Effect of Moringa leaf extract on Stem diameter of Chili

Treatment	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
T_0	0.41 f	0.70 f	.96 f	1.37 f	1.68 f
T_1	0.45 e	0.78 e	1.20 e	1.54 e	1.79 e
T_2	0.49 d	0.84 d	1.28 d	1.65 d	1.86 d
T_3	0.53 c	0.90 c	1.35 c	1.76 c	1.93 c
T_4	0.56 b	0.96 b	1.41 b	1.84 b	1.98 b
T_5	0.61 a	1.03 a	1.47 a	1.93 a	2.12 a
Level of significance	**	**	**	**	**
SE(±)	0.01	0.02	0.03	0.01	0.02

4.2 Yield contributing parameters

4.2.1 Days of first flowering after DAT

Significant variation was observed on days of first flowering of chili plant when different doses of moringa leaf extract (MLE) were applied (Table 3). Results indicated that the lower days for first flowering was recorded in T_5 treatment and highest days for first flowering was recorded in T_0 treatment. T_5 treatment is significantly different from others treatment. MLE stimulated the growth of flowers. While T_0 treatment received no MLE at all, T_5 treatment received a significant quantity of MLE. The first flowering of the chili plant may be accelerated by high doses of moringa leaf extract, resulting in the early flowering in chili plant.

Table 5. Effect of Moringa leaf extract on days of first flowering of *Capsicum annuum L.*

Treatment	Days of first flowering after DAT
T_0	**62.14 f**
T_1	**60.57 e**
T_2	**58.57 d**
T_3	**56.14 c**
T_4	**53.85 b**
T_5	**51.42 a**
Level of significance	****
SE(±)	**.59**

*=significant at 5% levels of significance **=significant at 1% levels of significance

T_0: 0 ml (control), T_1: Moringa leaf extract sprayed at 15 ml, T_2: Moringa leaf extract sprayed at 30 ml, T_3: Moringa leaf extract sprayed at 45 ml, T_4: Moringa leaf extract sprayed at 60 ml, T_5: Moringa leaf extract sprayed at 75 ml

4.2.2 Fresh weight of shoot

Fresh weight of shoot of chili plant was significantly influenced by different level of moringa leaf extract (figure 3). Among the different treatments the highest fresh weight of shoot (364.93 g) was observed in T_5 treatment and lowest weight of shoot (276.32 g) was observed in T_0 treatment. T_5 treatment was treated with high amount of MLE while T_0 treatment was not treated any MLE. Presence of cytokinin in MLE solution induce cytokinin biosynthesis which translocate of stem reserves to recent shoot due to healthy plant growth (Rady *et al*.,2015). High level dose of moringa leaf extract might be increased the vegetative growth and development of chili plant that lead to highest fresh weight of shoot. Control condition T_0 did not show more performance than any treatments.

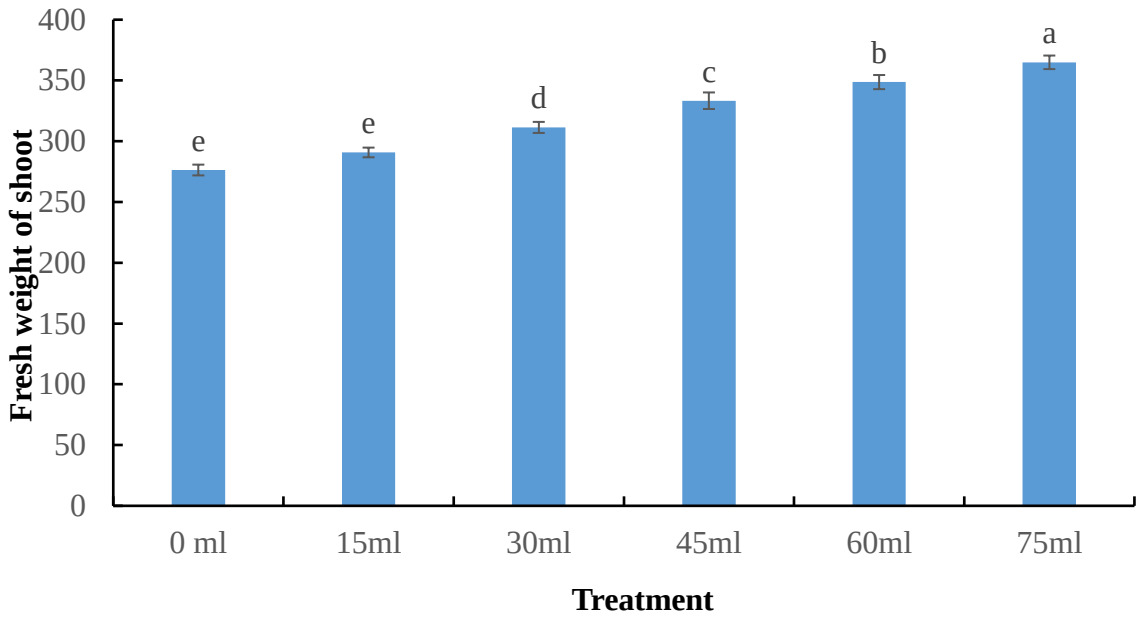

Figure 1. Effect of Moringa leaf extract on fresh weight of shoot of *Capsicum annuum L.*

4.2.3 Fresh weight of root

It is obvious that all the growth parameters were promoted with different MLE levels as compared to the control and it also occurred in fresh weight of root. Maximum fresh weight of root (84.22 g) occurred in T_5 treatment and lowest fresh of root (63.95 g) occurred in T_0 treatment. It might be due to the fact of high concentration of moringa leaf extract was enough to expand plant root by substances which promoted the growth. MLE contains a good amount micro and macro essential elements which was helped to increased the growth of chili plant root. T_5 treatment treated plant received more MLE compared to other plant and its roots growth was high compared to others treatment.

Table 6. Effect of Moringa leaf extract on fresh weight of root of *Capsicum annuum L.*

Treatment	Fresh weight of root
T_0	63.95 f
T_1	69.75 e
T_2	73.90 d
T_3	78.05 c
T_4	81.20 b
T_5	84.22 a
Level of significance	*
SE(±)	1.14

*=significant at 5% levels of significance **=significant at 1% levels of significance
T_0: 0 ml (control), T_1: Moringa leaf extract sprayed at 15 ml, T_2: Moringa leaf extract sprayed at 30 ml, T_3: Moringa leaf extract sprayed at 45 ml, T_4: Moringa leaf extract sprayed at 60 ml, T_5: Moringa leaf extract sprayed at 75 ml

4.2.4 Dry weight of shoot

Application of different level of Moringa leaf extract (MLE) showed significant variation of dry weight of shoot among different treatment in chili plant (Figure 4). Dry weight of shoot gradually increased with the increase of moringa leaf extract. The highest dry weight of shoot (51.84gm) was recorded in T_5 treatment and lowest dry weight of shoot (38.55gm) was recorded in T_0 treatment. High level dose of moringa leaf extract might be increased the vegetative growth and development of chili plant that lead to highest dry weight of shoot. In T_0 treatment dry weight of shoot is lowest compared to any other treatment because there is no MLE was applied in T_0 treatment.

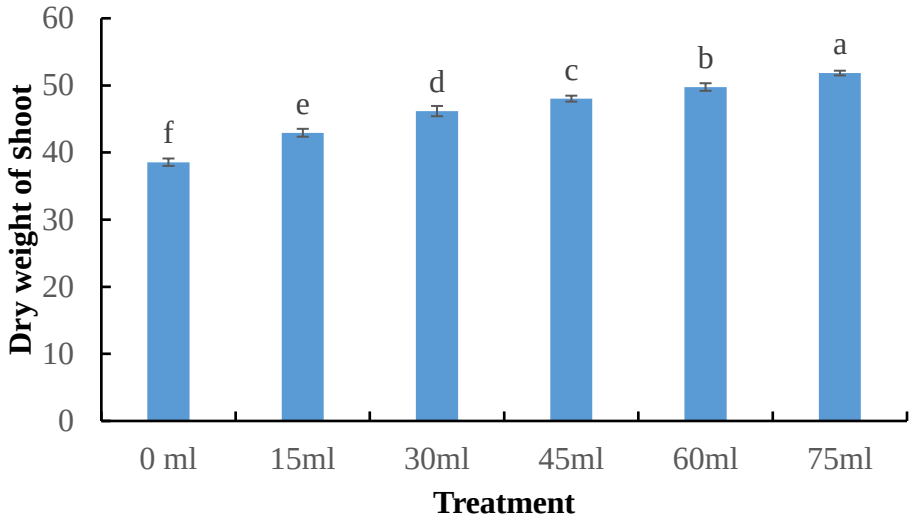

Figure 2. Effect of Moringa leaf extract on dry weight of shoot of *Capsicum annuum L.*

4.2.5 Dry weight of root

Dry weight of root was significantly varied among the different treatments due to different level of moringa leaf extract (Table 5). The highest dry weight of root (15.77 g) was recorded in T_5 treatment while the lowest dry weight of root (9.95 gm) was recorded in T_0 treatment. All the growth parameters were promoted with different MLE levels as compared to the control and it also occurred in dry weight of root. In T_5 treatment high amount of growth hormones and nutrients were presented that's why growth of root was high and finally dry weight of root was high in T_5 treatment.

Table 7. Effect of Moringa leaf extract on dry weight of root of *Capsicum annum* L

Treatment	Dry weight of root
T_0	9.95 f
T_1	11.02 e
T_2	11.91 d
T_3	12.98 c
T_4	14.04 b
T_5	15.77 a
Level of significance	**
SE(±)	.32

*=significant at 5% levels of significance **=significant at 1% levels of significance
T_0: 0 ml (control), T_1: Moringa leaf extract sprayed at 15 ml, T_2: Moringa leaf extract sprayed at 30 ml, T_3: Moringa leaf extract sprayed at 45 ml, T_4: Moringa leaf extract sprayed at 60 ml, T_5: Moringa leaf extract sprayed at 75 ml

4.2.6 Number of fruits

Application of different level of Moringa leaf extract (MLE) showed significant variation of number of fruits among different treatment in chili plant (figure 5). Number of fruits was increased gradually with the increase of moringa leaf extract. The highest number of fruits (194.42) was recorded in T_5 treatment and lowest number of fruits (126.28) was recorded in T_0 treatment. Doses of Moringa leaf extract was high in T_5 treatment and there is no moringa leaf extract was applied in T_0 treatment. That is why T_5 treatment might be found more growth hormones and nutrients compared to another treatment. As a result T_5 produced more fruits than another treatments.

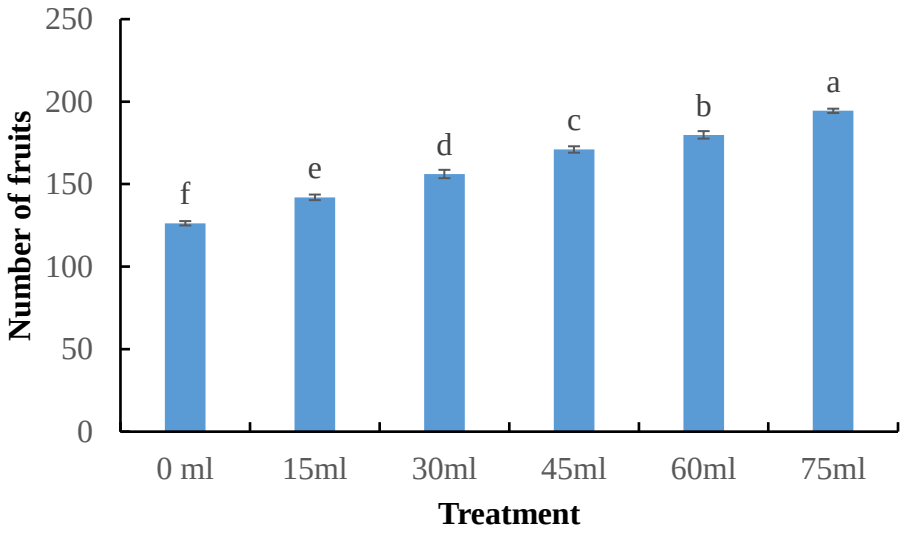

Figure 3. Effect of Moringa leaf extract on number of fruits of Chili

4.2.7 LENGTH OF FRUITS

Significant variation was observed on length of fruits in chili plant due to different level of treatments (Table 5). It was discovered that chili fruit lengths ranged from 9.07 to 11.17 cm on average. The highest length of fruits (9.06 cm) was found in T_5 treatment and lowest fresh weight of fruits (11.17cm) was found in T_0 treatment. Chili showed in average length of fruits of 9.50, 9.87, 10.41, 10.75cm at T_1, T_2, R_3, T_4 respectively. T_5 treatment treated plants fruit length was vigorous than any other treatments.

This result indicated that different level of moringa leaf extract (MLE) helped to increase length of fruits of chili. This might be caused due to present of different growth hormones and nutrients in MLE.

Table 8. Effect of Moringa leaf extract on length of fruits of *Capsicum annuum L.*

Treatment	Length of fruits
T_0	9.07 f
T_1	9.50 e
T_2	9.87 d
T_3	10.41 c
T_4	10.75 b
T_5	11.17 a
Level of significance	**
SE(±)	.12

*=significant at 5% levels of significance **=significant at 1% levels of significance

T_0: 0 ml (control), T_1: Moringa leaf extract sprayed at 15 ml, T_2: Moringa leaf extract sprayed at 30 ml, T_3: Moringa leaf extract sprayed at 45 ml, T_4: Moringa leaf extract sprayed at 60 ml, T_5: Moringa leaf extract sprayed at 75 ml

4.2.8 Weight of fruits for per treatment

The mean fresh weight of fruits of chili had been found to vary from 181.18 to 311.32gm. The highest fresh weight of fruits (311.32 g) was found in T_5 treatment and lowest fresh weight of fruits (181.18gm) was found in T_0 treatment. Chili showed in average fresh weight of fruits of 195.84, 240.30, 278.01, 277.99 g at T_1, T_2, R_3, T_4 respectively. High moringa leaf extract increased sink capacity through photo-assimilate from leaves which helped to produce quality fruits.

Higher dose of moringa leaf extract (MLE) in T_5 treatment showed higher weight of fruits in chili that was might be caused due to high amount of nutrients and growth hormones present in T_5 treatment which stimulated the weight of fruits. Jason (2013) found MLE increased crop production 25-30% that support this result.

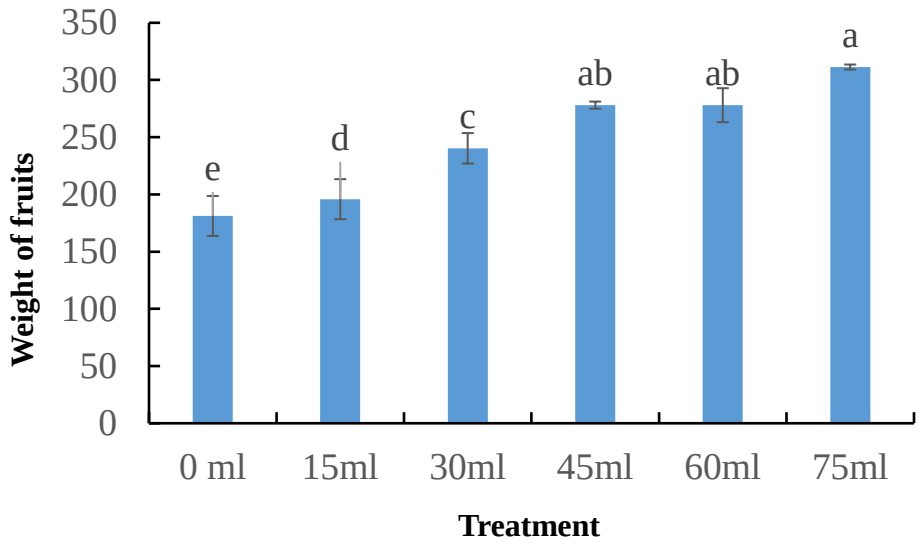

Figure 4. Effect of Moringa leaf extract on weight of fruits of *Capsicum annuum* L.

4.2.9 Yield of fruits (t/ha)

The yield of fruits of chili had been found to vary from 11.41 to 19.60 tha^{-1} (table 7) after two harvest. The highest yield of fruits (19.60tha^{-1}) was found in T_5 treatment and lowest fresh weight of fruits (11.41tha^{-1}) was found in T_0 treatment. Chili showed yield of fruits of 12.33, 15.13, 17.51, 17.50tha^{-1} at T_1, T_2, R_3, T_4 respectively. High level dose of moringa leaf extract might be increased the vegetative growth, development and fruits bearing of chili plant that lead to highest yield of fruits. In T_0 treatment field of fruits was lowest compared to any other treatment because there is no MLE was applied in T_0 treatment. Application of MLE with good concentration contain sufficient amount of stimulate substance that encouraged increasing cell division rate, cell enlargement, strengthens plants, eventually produce more and higher yield (Fugile, 2000). The finding of Jason (2013) was also supported this experiment.

Table 9. Effect of Moringa leaf extract on yield of fruits (t/ha) of chili

Treatment	Yields of fruits (t/ha)
T_0	11.41 d
T_1	12.33 d
T_2	15.13 c
T_3	17.51 ab
T_4	17.50 ab
T_5	19.60 a
Level of significance	*
SE(±)	8.83

*=significant at 5% levels of significance **=significant at 1% levels of significance

T_0: 0 ml (control), T_1: Moringa leaf extract sprayed at 15 ml, T_2: Moringa leaf extract sprayed at 30 ml, T_3: Moringa leaf extract sprayed at 45 ml, T_4: Moringa leaf extract sprayed at 60 ml, T_5: Moringa leaf extract sprayed at 75 ml

CHAPTER 5

SUMMERY AND CONCLUSION

5.1 SUMMERY

The experiment was performed at Agroforestry and environmental science research field of Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from December, 2021 to May, 2022 to evaluate the effect of moringa leaf extract on growth and yield of Capsicum annum L. The experiment was laid out in Randomized block resign (RCBD) with seven replications. This experiment comprised of single factor with six treatments. Treatments were T_0: 0 ml (control), T_1: Moringa leaf extract sprayed at 15 ml, T_2: Moringa leaf extract sprayed at 30 ml, T_3: Moringa leaf extract sprayed at 45 ml, T_4: Moringa leaf extract sprayed at 60 ml, T_5: Moringa leaf extract sprayed at 75ml. Total combination of treatments and replications were 42. This experiment was done by using chili (BARI Morich-2) which was collected from Horticulture research field, Sher-e-Bangla Agriculture University. Fifteen days Seedling were transplanted in pot. For preparing stock solution *moringa olifera* leaf was collected from Agroforestry and Environmental science research field, Sher-e-Bangla Agricultural University. Clean and dried plastic pot of 12 kg size were used for experiment. Each pot was filled with 10 kg previously prepared soil.

Data were collected on different growth and yield contributing parameters of chili like plant height, leaf number, branches number, stem diameter, first flowering days, fresh weight of shoot, fresh weight of root, dry weight of shoot, dry weight of root, number of fruits, length of fruits, weight of fruits from each plant of a treatment. Data were analyzed and difference between the means were evaluated by Duncan multiple Range test. The experimental results are summarized as follows.

Recorded data on different growth and yield contributing parameters were high in T_5 treatment compared to other treatments where plants were added in different level of moringa leaf extract. The significant variation was found all the parameters test. The results revealed that after 90 DAT the highest plant height (84.72 cm) was observed in T_5 treatment whereas lowest plant height (54.07 cm) in T_0 treatment. Again, maximum number of leaf (191.1) was observed in T_5 treatment and lowest number of leaf (126.1) after 90 DAT. The results also revealed that branches number and stem diameter (14.0 and 2.12cm respectively) is highest all the growth

stages in T_5 treatment and lowest branch number and stem diameter (10.42 and 1.68 cm) all the growth stages in T_0 treatment.

Regarding yield contributing parameters, the lowest days of first flowering (51.42 days) was observed in T_5 treatment and highest days of first flowering (62.14 days) was observed in T_0 treatment. Again, in term of fresh weight of shoot, fresh weight of root, dry weight of shoot, dry weight of root the highest result (364.93, 84.22, 51.84, 15.77 g respectively) were found in T_5 treatment whereas lowest result (276.32, 63.95, 38.55, 9.55 respectively) were found in T_0 treatment. Similarly, the highest number of fruits (194.28), length of fruits (11.17 cm), weight of fruits (311.32 g) were recorded in T_5 treatment and lowest number of fruits (126.28), length of fruits (9.07 cm), weight of fruits (181.18 g) were recorded in T_0 treatment. Again, highest total final yield of fruits (19.60 tha^{-1}) was observed in T_5 treatment and lowest yields of fruits (11.41 tha^{-1}) was observed in T_0 treatment.

5.2 CONCLUSION

From findings of the present study, it can be concluded that there was significant variation among different treatments in term of growth and yield of chili. T_5 treatment exhibited the highest results in respect of growth and yield compared to other treatments T_0, T_1, T_2, T_3, T_4. T_5 treatment treated chili plant showed best performance in term of growth and yield. T_0 (control) treatment treated chili plant showed the lowest performance in term of growth and yield.

The aim of the study was to explore effect of moringa leaf extract on growth and yield of chili plant. The results of the experiment showed that there were a positive impact of moringa leaf extract on growth and yield of chili. It was observed that high amount of MLE stimulated the growth and yield of chili plant.

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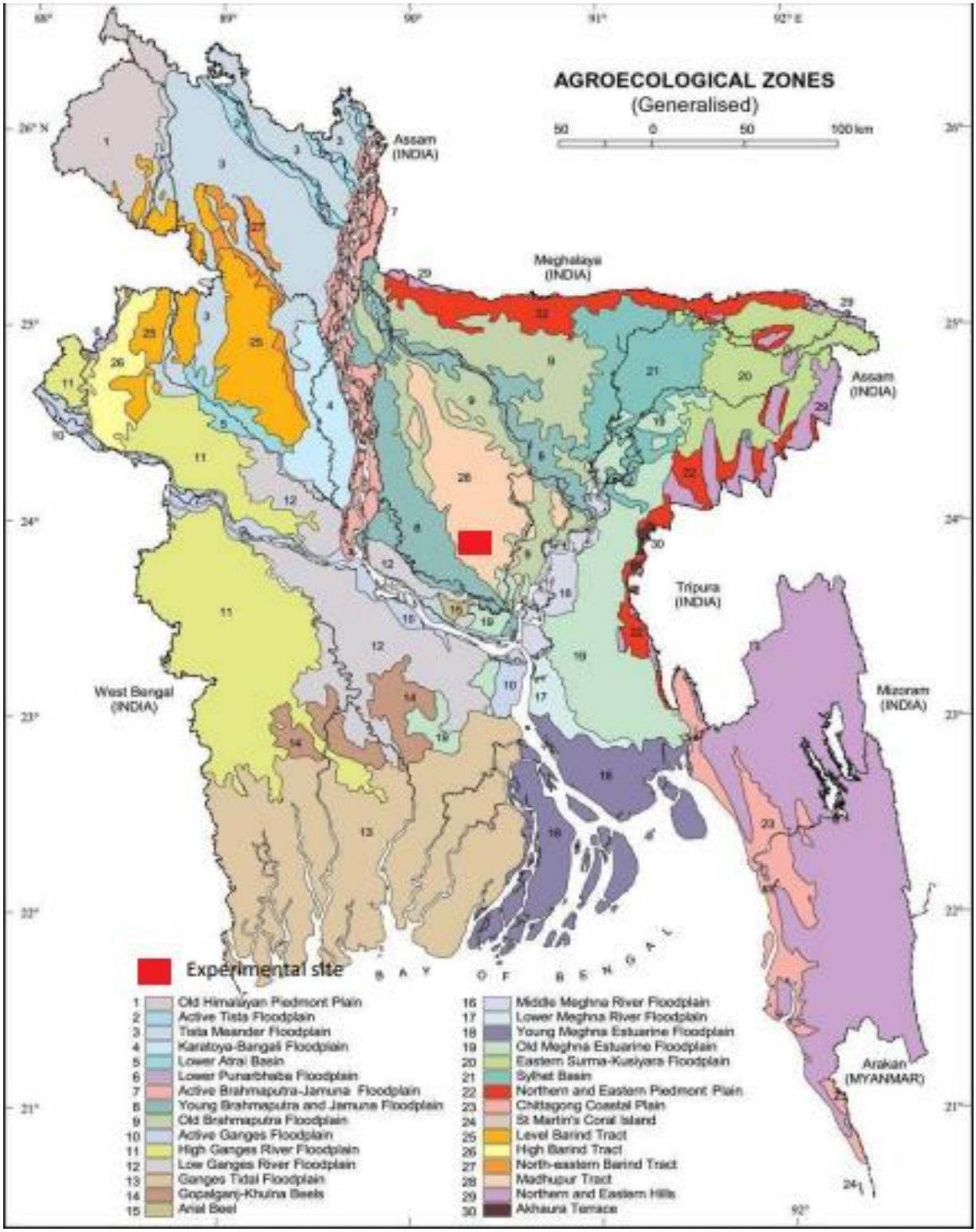
APPENDICES

Appendix 1. Agro-Ecological Zone of Bangladesh showing the experimental location



Appendix 2. Chemical composition analysis of moringa leaf extract according to Abdalla ((2014)

Chemical composition	Mg/100g.d.wt
Water	5.90
Protein	27.20
Fiber	19.20
Total sugar	38.60
Lipid	17.10
Ascorbic acid	3.26
Total caroteboids	2.24
Soluble phenols	2.24
Gibberellins	0.802
zeatin	0.936

Appendix 3. The mineral content of moringa leaf extract (MLE)

Mineral contents	mg/100g.d.wt
N	1.78
P	9.7
K	2.8
Mg	3.5
Ca	1.28
Fe	1.18
Cu	0.87
Zn	2.46

Appendix 4. 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)

Appendix 5. Analysis of variance of data on plant height of chili influenced by different concentrations of Moringa extract solution

Plant Height	Group	Sum of Squares	df	Mean Square	F	Sig.
15 DAT	Between groups	27.107	5	5.421	8.325	.000
	Within groups	23.443	36	0.651		
	total	50.550	41			
30 DAT	Between groups	118.985	5	23.797	16.336	.000
	Within groups	52.443	36	1.457		
	total	171.428	41			
45 DAT	Between group	512.485	5	102.497	24.829	.000
	Within group	148.614	36	4.128		
	total	661.099	41			
60 DAT	Between groups	2488.501	5	497.700	18.041	.000
	Within groups	993.149	36	27.587		
	total	3481.650	41			
75 DAT	Between groups	4048.690	5	809.738	34.421	.000
	Within groups	846.886	36	23.525		
	total	4895.576	41			
90 DAT	Between groups	4248.718	5	849.744	38.038	.000
	Within groups	804.211	36	22.339		
	total	5052.930	41			

Appendix 6. Analysis of variance of data on leaf number of chili influenced by different concentrations of Moringa extract solution

Number of leaf	Group	Sum of Squares	df	Mean Square	F	Sig.
15 DAT	Between groups	58.000	5	11.600	13.050	.000
	Within groups	32.000	36	0.889		
	total	90.000	41			
30 DAT	Between groups	1578.286	5	315.657	82.175	.000
	Within groups	138.286	36	3.841		
	total	1716.571	41			
45 DAT	Between group	4341.048	5	868.210	91.162	.000
	Within group	342.857	36	9.524		
	total	4683.905	41			
60 DAT	Between groups	9212.190	5	1842.438	115.611	.000
	Within groups	573.714	36	15.937		
	total	9785.905	41			
75 DAT	Between groups	10457.905	5	2091.581	112.624	.000
	Within groups	668.571	36	18.571		
	total	11126.476	41			
90 DAT	Between groups	19200.476	5	3840.095	293.600	.000
	Within groups	470.857	36	13.079		
	total	19671.333	41			

Appendix 7. Analysis of variance of data on number of branches influenced by different concentrations of Moringa extract solution

Number of branches	Group	Sum of Squares	df	Mean Square	F	Sig.
30 DAT	Between groups	71.071	5	14.214	10.789	.000
	Within groups	47.429	36	1.317		
	total	118.500	41			
45 DAT	Between group	93.048	5	18.610	16.630	.000
	Within group	40.286	36	1.119		
	total	133.333	41			
60 DAT	Between groups	103.833	5	20.767	20.767	.000
	Within groups	36.000	36	1.000		
	total	139.833	41			
75 DAT	Between groups	100.786	5	20.157	40.965	.000
	Within groups	17.714	36	0.492		
	total	118.500	41			
90 DAT	Between groups	55.619	5	11.124	50.057	.000
	Within groups	8.000	36	0.222		
	total	63.619	41			

Appendix 9. Analysis of variance of data on stem diameter of chili influenced by different concentrations of Moringa extract solution

Stem diameter	Group	Sum of Squares	df	Mean Square	F	Sig.
30 DAT	Between groups	.189	5	0.038	88.074	.000
	Within groups	.015	36	.000		
	total	.205	41			
45 DAT	Between group	.497	5	0.099	71.731	.000
	Within group	.050	36	0.001		
	total	.547	41			
60 DAT	Between groups	1.194	5	0.239	389.337	.000
	Within groups	.022	36	0.001		
	total	1.216	41			
75 DAT	Between groups	1.491	5	0.298	286.756	.000
	Within groups	.037	36	0.001		
	total	1.528	41			
90 DAT	Between groups	.820	5	0.164	164.949	.000
	Within groups	.036	36	0.001		
	total	.856	41			

Appendix 10 Analysis of variance of data on fresh weight of shoot of chili influenced by different concentrations of Moringa extract solution

	Group	Sum of Squares	df	Mean Square	F	Sig.
FWS	Between groups	40955.729	5	8191.146	41.951	.000
	Within groups	7029.105	36	195.253		
	total	47984.834	41			

Appendix 11. Analysis of variance of data on fresh weight of root of chili influenced by different concentrations of Moringa extract solution

	Group	Sum of Squares	df	Mean Square	F	Sig.
FWR	Between groups	1983.753	5	396.751	56.525	.000
	Within groups	252.686	36	7.019		
	total	2236.438	41			

Appendix 12. Analysis of variance of data on dry weight of shoot of chili influenced by different concentrations of Moringa extract solution

	Group	Sum of Squares	df	Mean Square	F	Sig.
DWS	Between groups	818.021	5	163.604	74.481	.000
	Within groups	79.077	36	2.197		
	total	897.098	41			

Appendix 13. Analysis of variance of data on dry weight of root of chili influenced by different concentrations of Moringa extract solution

	Group	Sum of Squares	df	Mean Square	F	Sig.
DWR	Between groups	155.478	5	31.096	56.767	.000
	Within groups	19.720	36	0.548		
	total	175.198	41			

Appendix 14. Analysis of variance of data on fruit number of chili influenced by different concentrations of Moringa extract solution

	Group	Sum of Squares	df	Mean Square	F	Sig.
FN	Between groups	22123.048	5	4424.610	174.875	.000
	Within groups	910.857	36	25.302		
	total	23033.905	41			

Appendix 15. Analysis of variance of data on length of fruit of chili influenced by different concentrations of Moringa extract solution

	Group	Sum of Squares	df	Mean Square	F	Sig.
LN	Between groups	22.022	5	4.404	171.372	.000
	Within groups	.925	36	0.026		
	total	22.947	41			

Appendix 16. Analysis of variance of data on weight of fruits of chili influenced by different concentrations of Moringa extract solution

	Group	Sum of Squares	df	Mean Square	F	Sig.
WF	Between groups	91374.602	5	18274.920	15.314	.000
	Within groups	42960.340	36	1193.343		
	total	134334.942	41			

PLATES

Plate 1. Soil preparation and Transplanting of seedling

Plate 2. Collection of data


Plate 3. Collection of data


Plate 5. watering and weeding


Plate 5. Field view of mature plant


Plate 6. Harvesting and weighting of fresh fruits

Plate 7. Weighting of dry shoots and roots