EFFECT OF DIFFERENT PHYTOHORMONES ON ROOT AND SHOOT DEVELOPMENT OF MORINGA CUTTINGS

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EFFECT OF DIFFERENT PHYTOHORMONES ON ROOT AND SHOOT DEVELOPMENT OF MORINGA CUTTINGS

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF DIFFERENT PHYTOHORMONES ON ROOT AND SHOOT DEVELOPMENT OF MORINGA CUTTINGS"** submitted to the Department of Agroforestry and Environmental Science, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE** in **AGROFORESTRY AND ENVIRONMENTAL SCIENCE**, embodies the result of a piece of bona fide research work carried out by **MURTOZA HELAL**, Registration No. 13-05347 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

Dated: June, 2020

Dhaka, Bangladesh

Md. Golam Jilani Helal
Assistant Professor
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Dedicated to
My
Beloved Parents

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EFFECT OF DIFFERENT PHYTOHORMONES ON ROOT AND SHOOT DEVELOPMENT OF MORINGA CUTTINGS

ABSTRACT

The experiment was conducted at the Agroforestry Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka during the period from April 2019 to September 2019 to study the effect of different phytohormones on root and shoot development of Moringa cuttings. Cuttings were grown with five treatments viz., (i) T_1 (Honey), (ii) T_2 (Rooton hormone), (iii) T_3 (Auxin), (iv) T_4 (Cutting hormone) and (v) T_5 (Water as control) by following the single factor Completely Randomized Design (CRD). Each treatment was replicated eight times. Data on the selected parameters were collected from randomly selected Cuttings of each treatment and analyzed statistically. In this experiment the highest results in respective parameter were found from T_1 (Honey) treatment. The highest number of buds at 15, 30, 45 and 60 days after transplanting (DAT) (3, 4.33, 4.33 and 6.67), number of branches per plant (6.67), number of leaves per plant (53.67), leaves length per plant (71 cm), leaves base length per leaf (15.33 cm), third internode length of leaves from top (9.6 cm) were found in T_1 treatment. The lowest number of buds found at 15, 30, 45 and 60 DAT (0.67, 1.33, 1.33 and 1.67), number of branches per plant (1.67), number of leaves per plant (13.67), leaves length per plant (44.67 cm), leaves base length per leaf (13.33 cm) and third internode length of leaves from top (7.57 cm) found in T_4 treatment. Maximum number of rachilas per leaves (17.33), number of roots per plant (20.33), root length per plant (18 cm), fresh weight of roots per plant (26.24 g), fresh weight of shoot per plant (730.51 g), dry weight of roots (5.98 g) and dry weight of shoot (158.07 g) found in T_1 Treatment. Minimum number of rachilas (14), number of roots per plant (9.33), root length per plant (9.33 cm), fresh weight of roots per plant (9.01 g), fresh weight of shoot per plant (149.11 g), dry weight of roots (2.10 g) and lowest weight of shoot per plant (33.76 g) found in T_4 treatment. The highest number of leaflets per leaves found with cutting hormone (398.67) and the lowest number of leaflets number found with Honey (331.67). Thus, it revealed that treatment T_1 (Honey) could successfully be used as rooting phytohormone in Moringa cutting propagation.

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LIST OF ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BCSRI	=	Bangladesh Council of Scientific Research Institute
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAT	=	Days After Transplanting
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
ml	=	Mili Litre
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
PGR	=	Plant Growth Regulators
^oC	=	Degree Celceous
%	=	Percentage
IAA	=	Indole Acetic Acid
GM	=	Geometric mean
CPA	=	Chloro-phenoxyacetic Acid
P	=	Phosphorus
K	=	Potassium
ABT	=	Amino Benzotriazole
L	=	Litre
NAA	=	Naphthalene Acetic Acid
USA	=	United States of America
WHO	=	World Health Organization
GA_3	=	Gibberellic Acid
ABA	=	Abscisic acid
MH	=	Maleic Hydrazide

CHAPTER I

INTRODUCTION

Moringa oleifera is a fast growing, drought resistant tree of the family Moringaceae, native to tropical and subtropical regions of South Asia. Almost all parts of Moringa are edible. *M. oleifera* is a plant that has been praised for its health benefits for thousands of years. It is very rich in healthy antioxidants and bioactive plant compounds. It is the most widely cultivated species in the genus *Moringa* and the only genus in the plant family Moringaceae (Olson, 2010). *M. oleifera* is cultivated for its leaves, pods, and/or its kernels for oil extraction and water purification. The yields vary widely depending on season, variety, fertilization, and irrigation regimen. Moringa yields best under warm, dry conditions with some supplemental fertilizer and irrigation (Ted, 2011).

Leaves are the most nutritious part of the plant, being a significant source of vitamin B, vitamin C, provitamin A as beta-carotene, vitamin K, manganese and protein, among other essential nutrients (Peter, 2008). The seed pods/fruits, even when cooked by boiling, remain particularly high in vitamin C (which may be degraded variably by cooking) and are also a good source of dietary fiber, potassium, magnesium and manganese (*Nutritiondata.com*). Seeds, sometimes removed from more mature pods and eaten like peas or roasted like nuts, contain high levels of vitamin C and moderate amounts of B vitamins and dietary minerals. Roots are shredded and used as a condiment with sharp flavor qualities deriving from significant content of polyphenols (Atawodi *et al.*, 2010). Moringa is rich in antioxidants, it lowers blood sugar levels, reduce inflammation, cholesterol, protect against arsenic toxicity; protecting and nursing skin, hair, kidney disorders, liver; treating edema, stomach complaints, mood disorders, asthma, diabetes, anemia and sickle cell disease; reducing high blood pressure, helping wounds to heal, making bone healthier fighting against bacterial disease; preventing and treating cancer

(*iyarkaiankadi.com*). A 100-g sample of dry Moringa leaves contains 10 times more vitamin A than is found in carrots, 7 times more vitamin C than found in oranges, 17 times more Ca than found in milk, 15 times more K than found in bananas, 25 times more Fe than found in spinach, 4 times more protein than found in eggs and 9 times more protein than contained in yoghurt (Fahey, 2005; Witt, 2016). Moringa is the most nutrient rich plant discovered to date with 90+ nutritional compounds including 46 antioxidants and 36 anti-inflammatories substances (Siddhuraju and Becker, 2003; Anwar et al., 2005; Fahey, 2005).

Phytohormones are signal molecules produced within plants, which occur in extremely low concentrations. Plant hormones control all aspects of growth and development, from embryogenesis, the regulation of organ size, pathogen defense, stress tolerance and through to reproductive development (Méndez et al., 2019). Plant hormones affect gene expression and transcription levels, cellular division, and growth. They are naturally produced within plants, though very similar chemicals are produced by fungi and bacteria that can also affect plant growth (Srivastava, 2002). A large number of related chemical compounds are synthesized by human. They are used to regulate the growth of cultivated plants, weeds, and in vitro-grown plants and plant cells; these man made compounds are called plant growth regulators (PGRs). Early in the study of plant hormones, "phytohormones" was the commonly used term, but its use is less widely applied now. Auxin are compounds that positively influence cell enlargement, bud formation and root initiation. They also promote the production of other hormones and in conjunction with Cytokinin, they control the growth of stems, roots, and fruits, and convert stems into flowers (Osborne and McManus, 2005). They affect cell elongation by altering cell wall plasticity. They stimulate cambium, a subtype of meristem cells, to divide and in stems cause secondary xylem to differentiate. Auxin act to inhibit the growth of buds lower down the stems (apical dominance), and also to promote lateral and adventitious root development and growth. Leaf abscission is initiated

by the growing point of a plant ceasing to produce Auxin. Auxin in seeds regulate specific protein synthesis, as they develop within the flower after pollination, causing the flower to develop a fruit to contain the developing seeds (Walz *et al.*, 2002). Honey is a sweet, viscous food substance made by bees and some related insects. Bees produce honey from the sugary secretions of plants (floral nectar) or from secretions of other insects (such as honeydew), by regurgitation, enzymatic activity, and water evaporation. Bees store honey in wax structures called honeycombs (Crane, 1990). A mixture of sugars and other carbohydrates, honey is mainly fructose (about 38%) and glucose (about 32%), with remaining sugars including maltose, sucrose, and other complex carbohydrates (National Honey Board, USA. 2011). Honey can be a good nutrients supplier for plants. It gives fermented solution that helps fragmented its molecule and easy to take for plants root.

The demand of nutritive food in Bangladesh and around the world is increasing rapidly. Driven by economic growth, rising incomes and urbanization, demand is shifting away from traditional staples toward high-value vegetable commodities. In Bangladesh, additional demand for these commodities is projected to be worth about $10 billion by 2020. More than 80% of people living on less than $2.5 a day in Bangladesh live in rural areas (Rahim, 2017). This spatial distribution of poverty makes capitalizing on the opportunities afforded by high value vegetables like Moringa. Moringa production an important strategic priority for those seeking to reduce malnutrition in the country. Insufficient processing capacity, the lack of cold storage facilities or a functioning cold chain, and the persistence of transport bottlenecks are significant constraints to high value Moringa production in Bangladesh. The promise of generating higher income and increased export revenues by accessing international markets is matched by the challenges of meeting the exacting quality and safety standards that apply in those markets and by the prospect of having to compete with high quality imports from those markets. There

is limited processing of Moringa in Bangladesh leading to value addition. The majority of Moringa produce is not processed at all and thus lacks in value addition. Most farmers do not have adequate knowledge of Moringa processing and value addition. They also not have enough quality seedlings for increasing Moringa production. But it can fulfill nutritious demand of our population with lower cost and easy procedure of eating. So, we can alleviate our nutrition problem and secure our health security by cultivating Moringa. In our country most of the people eat only Moringa fruits as food. We need to encourage them to take Moringa leaves as food supplements which having the maximum nutrient value. For that we need to produce more Moringa products and distributed it into whole country. To popularize the beneficial utilities of this super food throughout our country we need to increase Moringa cultivation by producing quality seedlings that ensure better production.

Therefore, this experiment was conducted to find out better plant growth regulator for Moringa propagation to produce better quality Moringa saplings. Quality saplings will ensure better production which will increase value and quality of product and increase nutrient quantity of the Moringa product. Hence, considering the above circumstances, the present study was undertaken with the following objectives:

- To assess the effect of phytohormones on root development on Moringa cuttings.
- To assess the effect of phytohormones on shoot development of Moringa cuttings.
- To identify suitable phytohormone(s) for root and shoot development in Moringa cuttings propagation.

CHAPTER II

REVIEW OF LITERATURE

This research was undertaken to observe the effect of different phytohormones on root and shoot development of Moringa cuttings. Studies on Moringa with different phytohormones are very limited. So that literatures related to these aspects are very limited in our country and abroad. However, literatures related to the plant growth regulators and Moringa crops, performance of different plant growth regulators on different trees and vegetables were collected through reviewing of journals, thesis, internet browsing, reports, newspaper and other form of publications are presented in this Chapter in the following sections.

2.1 Moringa

Moringa oleifera is a fast growing, drought resistant tree of the family Moringaceae, native to the Indian subcontinent (CABI, 2018). Common names of Moringa are drumstick tree (from the long, slender, triangular seed-pods), horseradish tree (from the taste of the roots, which resembles horseradish), and ben oil tree or benzolive tree (from the oil which is derived from the seeds) (USDA, 2017).

It is widely cultivated for its young seed pods and leaves used as vegetables and for traditional herbal medicine. It is also used for water purification (Kalibbala *et al.,* 2009). Although listed as an invasive species in several countries, *M. oleifera* has not been observed invading intact habitats or displacing native flora, and so should be regarded at present as a widely cultivated species with low invasive potential (CABI, 2018).

M. oleifera is a fast-growing, deciduous tree that can reach a height of 10–12 m (32–40 ft) and trunk diameter of 45 cm (1.5 ft) (Parotta and John, 1993). The bark has a whitish-grey color and is surrounded by thick cork. Young shoots have purplish or

greenish-white, hairy bark. The tree has an open crown of drooping, fragile branches and the leaves build up a feathery foliage of tripinnate leaves.

The flowers are fragrant and hermaphroditic, surrounded by five unequal, thinly veined, yellowish-white petals. The flowers are about 1.0–1.5 cm (1/2") long and 2.0 cm (3/4") broad. They grow on slender, hairy stalks in spreading or drooping flower clusters which have a length of 10–25 cm. Flowering begins within the first six months after planting. In seasonally cool regions, flowering only occurs once a year between April and June. In more constant seasonal temperatures and with constant rainfall, flowering can happen twice or even all year-round (Parotta and John, 1993).

The fruit is a hanging, three-sided brown capsule of 20–45 cm size which holds dark brown, globular seeds with a diameter around 1 cm. The seeds have three whitish papery wings and are dispersed by wind and water. In cultivation, it is often cut back annually to 1–2 m (3–6 ft) and allowed to regrow so the pods and leaves remain within arm's reach (Parotta and John, 1993).

The Moringa tree is grown mainly in semiarid, tropical, and subtropical areas, corresponding in the United States to USDA hardiness zones 9 and 10. It tolerates a wide range of soil conditions but prefers a neutral to slightly acidic (pH 6.3 to 7.0), well-drained sandy or loamy soil. In waterlogged soil, the roots have a tendency to rot. Moringa is a sun- and heat-loving plant, and does not tolerate freezing or frost. Moringa is particularly suitable for dry regions, as it can be grown using rainwater without expensive irrigation techniques (Radovich and Ted, 2011).

India is the largest producer of Moringa, with an annual production of 1.2 million tons of fruits from an area of 380 km^2. Moringa is grown in home gardens and as living fences in South Asia and Southeast Asia, where it is commonly sold in local markets. In the Philippines and Indonesia, it is commonly grown for its leaves which

are used as food. Moringa is also actively cultivated by the World Vegetable Center in Taiwan, a center for vegetable research. More generally, Moringa grows in the wild or is cultivated in Central America and the Caribbean, northern countries of South America, Africa, South & Southeast Asia and various countries of Oceania. As of 2010, cultivation in Hawaii, for commercial distribution in the United States, was in its early stages (Radovich and Ted, 2011).

M. oleifera can be cultivated for its leaves, pods, and/or its kernels for oil extraction and water purification. The yields vary widely, depending on season, variety, fertilization, and irrigation regimen. Moringa yields best under warm, dry conditions with some supplemental fertilizer and irrigation. Harvest is done manually with knives, sickles, and stabs with hooks attached. Pollarding, coppicing, and lopping or pruning are recommended to promote branching, increase production, and facilitate harvesting (Grubben, 2004).

2.2 Importance of Moringa and its seedling production

Moringa is an effective remedy for malnutrition. It is rich in nutrition owing to the presence of a variety of essential phytochemicals present in its leaves, pods and seeds. In fact, Moringa is said to provide 7 times more vitamin C than oranges, 10 times more vitamin A than carrots, 17 times more calcium than milk, 9 times more protein than yoghurt, 15 times more potassium than bananas and 25 times more iron than spinach (Rockwood *et. al.*, 2013).

The fact that Moringa is easily cultivable makes it a sustainable remedy for malnutrition. Countries like Senegal and Benin treat children with moringa (Kasolo *et al.,* 2010). Children deprived of breast milk tend to show symptoms of malnutrition. Galactagogues are generally prescribed to lactating mothers to augment milk production. The galactagogue, made of phytosterols, acts as a precursor for hormones required for reproductive growth. Moringa is rich in

phytosterols like stigmasterol, sitosterol and kampesterol which are precursors for hormones. These compounds increase the estrogen production, which in turn stimulates the proliferation of the mammary gland ducts to produce milk. It is used to treat malnutrition in children younger than 3 years (Titi and Estiasih, 2013). About 6 spoonful of leaf powder can meet a woman's daily iron and calcium requirements, during pregnancy. This study provides an overview on the cultivation nutritional values, medicinal properties for commercial use and pharmacological properties of Moringa. There are no elaborate reports on treatment of diabetes and cancer using Moringa.

Normally moringa seedling produced from stem cutting. In this case seedling production rate is lower and quality of the seedling can't be ensured. In the nursery normally seedling is growing in the media containing cow dung and soil mixture. There moringa seedling were gather minimum attention of nursery man. So, we can tell moringa seedling production face negligence due to other fruits and flower seedling production. That's why phytohormones used to assess the difference the result of Moringa seedling production and it showed significant difference in every factors of yield.

2.3 Phytohormones

Phytohormones are signal molecules produced within plants, which occur in extremely low concentrations. Plant hormones control all aspects of growth and development, from embryogenesis, the regulation of organ size, pathogen defense, stress tolerance and through to reproductive development (Méndez et al., 2019). Unlike in animals (in which hormone production is restricted to specialized glands) each plant cell is capable of producing hormones. Went and Thimann (1937) coined the term "phytohormone" and used it in the title of their book.

Phytohormones occur across the plant kingdom, and even in algae, where they have similar functions to those seen in higher plants (Shishova *et. al*., 2007). Some phytohormones also occur in microorganisms, such as unicellular fungi and bacteria, however in these cases they do not play a hormonal role and can better be regarded as secondary metabolites (Rademacher, 1994).

The word hormone is derived from Greek, meaning set in motion. Plant hormones affect gene expression and transcription levels, cellular division, and growth. They are naturally produced within plants, though very similar chemicals are produced by fungi and bacteria that can also affect plant growth (Srivastava, 2002). A large number of related chemical compounds are synthesized by humans. They are used to regulate the growth of cultivated plants, weeds, and in vitro-grown plants and plant cells; these manmade compounds are called plant growth regulators or PGRs for short.

Plant hormones are not nutrients, but chemicals that in small amounts promote and influence the growth, development and differentiation of cells and tissues (Öpik *et. al.,* 2005). The biosynthesis of plant hormones within plant tissues is often diffuse and not always localized. Plants lack glands to produce and store hormones, because, unlike animals which have two circulatory systems (lymphatic and cardiovascular) powered by a heart that moves fluids around the body plants use more passive means to move chemicals around their bodies. Plants utilize simple chemicals as hormones, which move more easily through their tissues. They are often produced and used on a local basis within the plant body. Plant cells produce hormones that affect even different regions of the cell producing the hormone. Hormones are transported within the plant by utilizing four types of movements. For localized movement, cytoplasmic streaming within cells and slow diffusion of ions and molecules between cells are utilized. Vascular tissues are used to move hormones from one part of the plant to another; these include sieve tubes or phloem

that move sugars from the leaves to the roots and flowers, and xylem that moves water and mineral solutes from the roots to the foliage.

Not all plant cells respond to hormones, but those cells that do are programmed to respond at specific points in their growth cycle. The greatest effects occur at specific stages during the cell's life, with diminished effects occurring before or after this period. Plants need hormones at very specific times during plant growth and at specific locations. They also need to disengage the effects that hormones have when they are no longer needed. The production of hormones occurs very often at sites of active growth within the meristems, before cells have fully differentiated. After production, they are sometimes moved to other parts of the plant, where they cause an immediate effect; or they can be stored in cells to be released later. Plants use different pathways to regulate internal hormone quantities and moderate their effects; they can regulate the amount of chemicals used to biosynthesize hormones. They can store them in cells, inactivate them, or cannibalize already-formed hormones by conjugating them with carbohydrates, amino acids, or peptides. Plants can also break down hormones chemically, effectively destroying them. Plant hormones frequently regulate the concentrations of other plant hormones (Swarup *et al.,* 2007). Plants also move hormones around the plant diluting their concentrations.

The concentration of hormones required for plant responses are very low (10^{-6} to 10^{-5} mol/L). Because of these low concentrations, it has been very difficult to study plant hormones, and only since the late 1970s have scientists been able to start piecing together their effects and relationships to plant physiology (Srivastava, 2002). Much of the early work on plant hormones involved studying plants that were genetically deficient in one or involved the use of tissue-cultured plants grown *in vitro* that were subjected to differing ratios of hormones, and the resultant growth compared. The earliest scientific observation and study dates to the 1880s;

the determination and observation of plant hormones and their identification was spread out over the next 70 years.

Different hormones can be sorted into different classes, depending on their chemical structures. Within each class of hormone, chemical structures can vary, but all members of the same class have similar physiological effects. Initial research into plant hormones identified five major classes: abscisic acid, auxins, cytokinins, ethylene, and gibberellins (Thomas and Thomas, 1979). This list was later expanded, and brassinosteroids, jasmonates, salicylic acid, and strigolactones are now also considered major plant hormones. Additionally, there are several other compounds that serve functions similar to the major hormones, but their status as bone fide hormones is still debated.

2.3.1 Auxin

Auxins (plural of Auxin) are a class of plant-growth regulators with some morphogen-like characteristics. Auxins play a cardinal role in coordination of many growth and behavioral processes in plant life cycles and are essential for plant body development. The Dutch biologist Frits Warmolt Went first described Auxins and their role in plant growth in the 1920s. Kenneth V. Thimann (1904-1997) became the first to isolate one of these phytohormones and to determine its chemical structure as indole-3-acetic acid (IAA). Went and Thimann co-authored a book on plant hormones, Phytohormones, in 1937.

Auxins were the first of the major plant hormones to be discovered. They derive their name from the Greek word *auxein* mean “to grow or increase". Auxin is present in all parts of a plant, although in very different concentrations. The concentration in each position is crucial developmental information, so it is subject to tight regulation through both metabolism and transport. The result is the Auxin creates "patterns" of Auxin concentration maxima and minima in the plant body,

which in turn guide further development of respective cells, and ultimately of the plant as a whole.

The dynamic and environment responsive pattern of Auxin distribution within the plant is a key factor for plant growth, its reaction to its environment, and specifically for development of plant organs such as leaves or flowers. It is achieved through very complex and well-coordinated active transport of Auxin molecules from cell to cell throughout the plant body by the so-called polar Auxin transport (Friml, 2003). Thus, a plant can (as a whole) react to external conditions and adjust to them, without requiring a nervous system. Auxins typically act in concert with, or in opposition to, other plant hormones. For example, the ratio of Auxin to Cytokinin in certain plant tissues determines initiation of root versus shoot buds.

On the molecular level, all Auxins are compounds with an aromatic ring and a carboxylic acid group (Taiz and Zeiger, 1998). The most important member of the Auxin family is indole-3-acetic acid (IAA), which generates the majority of Auxin effects in intact plants, and is the most potent native Auxin. And as native Auxin, its equilibrium is controlled in many ways in plants, from synthesis, through possible conjugation to degradation of its molecules, always according to the requirements of the situation (Zeiger *et. al*, 1993).

Five naturally occurring Auxins in plants include indole-3-acetic acid, 4-chloroindole-3-acetic acid, phenylacetic acid, indole-3-butyric acid, and indole-3-propionic acid (Ludwig-Müller, 2011). However, most of the knowledge described so far in Auxin biology and as described in the sections which follow, apply basically to IAA; the other three endogenous Auxins seems to have marginal importance for intact plants in natural environments. Alongside endogenous Auxins, scientists and manufacturers have developed many synthetic compounds with axenic activity.

Synthetic Auxin analogs include 1-naphthaleneacetic acid, 2, 4-dichlorophenoxy acetic acid (2, 4-D) and many others. Some synthetic Auxins, such as 2, 4-D and 2, 4, 5-trichlorophenoxyacetic acid (2, 4, 5-T), are sold as herbicides. Broad-leaf plants (dicots), such as dandelions, are much more susceptible to Auxins than narrow-leaf plants (monocots) such as grasses and cereal crops, making these synthetic Auxins valuable as herbicides (Simon and Petrášek, 2011).

Auxin regulate growth, particularly by stimulating cell elongation in stems. Auxins also play a role in cell division and differentiation, in fruit development, in the formation of roots from cuttings, in the inhibition of lateral branching (apical dominance), and in leaf fall (abscission). Auxins help to develop at all levels in plants, from the cellular level, through organs, and ultimately to the whole plant. When a plant cell comes into contact with Auxin, it causes dramatic changes in gene expression, with many genes up- or down-regulated. The precise mechanisms by which this occurs are still an area of active research, but there is now a general consensus on at least two Auxin signaling pathways (Leyser and Ottoline, 2018).

Auxin participates in phototropism, geotropism, hydrotropism and other developmental changes. The uneven distribution of Auxin, due to environmental cues, such as unidirectional light or gravity force, results in uneven plant tissue growth, and generally, Auxin governs the form and shape of the plant body, direction and strength of growth of all organs, and their mutual interaction (Benková *et al*., 2003).

Auxin stimulates cell elongation by stimulating wall-loosening factors, such as elastins, to loosen cell walls. The effect is stronger if gibberellins are also present. Auxin also stimulates cell division if Cytokinins are present. When Auxin and Cytokinin are applied to callus, rooting can be generated if the Auxin concentration is higher than Cytokinin concentration. Xylem tissues can be generated when the

Auxin concentration is equal to the Cytokinins. Auxin also induces sugar and mineral accumulation at the site of application. Auxin induces the formation and organization of phloem and xylem. When the plant is wounded, the Auxin may induce the cell differentiation and regeneration of the vascular tissues (Aloni *et al.,* 2006)

Auxins promote root initiation (Chambers, 1999). Auxin induces both growth of pre-existing roots and adventitious root formation, i.e., branching of the roots. As more native Auxin is transported down the stem to the roots, the overall development of the roots is stimulated. If the source of Auxin is removed, such as by trimming the tips of stems, the roots are less stimulated accordingly, and growth of stem is supported instead.

Auxin induces shoot apical dominance; the axillary buds are inhibited by Auxin, as a high concentration of Auxin directly stimulates ethylene synthesis in axillary buds, causing inhibition of their growth and potentiation of apical dominance. When the apex of the plant is removed, the inhibitory effect is removed and the growth of lateral buds is enhanced. Auxin is sent to the part of the plant facing away from the light, where it promotes cell elongation, thus causing the plant to bend towards the light (Jiří Friml Lab, 2012).

Auxin is required for fruit growth and development and delays fruit senescence. When seeds are removed from strawberries, fruit growth is stopped; exogenous Auxin stimulates the growth in fruits with seeds removed. For fruit with unfertilized seeds, exogenous Auxin results in parthenocarpy ("virgin-fruit" growth). Fruits form abnormal morphologies when Auxin transport is disturbed (Nemhauser *et al.,* 2000). Auxin plays also a minor role in the initiation of flowering and development of reproductive organs. In low concentrations, it can delay the senescence of flowers. A number of plant mutants have been described that affect flowering and

have deficiencies in either Auxin synthesis or transport. In maize, one example is bif2 barren inflorescence2 (McSteen *et al.,* 2007). In low concentrations, Auxin can inhibit ethylene formation and transport of precursor in plants; however, high concentrations can induce the synthesis of ethylene (Yu and Yang, 1979).

2.3.2 Honey

Honey is a sweet, viscous food substance made by honey bees and some related insects. Bees produce honey from the sugary secretions of plants (floral nectar) or from secretions of other insects (such as honeydew), by regurgitation, enzymatic activity and water evaporation. Bees store honey in wax structures called honeycombs (Crane *et al.,* 1984). The variety of honey produced by honey bees (the genus *Apis*) is the best-known, due to its worldwide commercial production and human consumption (Crane and Eva, 1999). Honey is collected from wild bee colonies, or from hives of domesticated bees, a practice known as beekeeping or apiculture.

Honey gets its sweetness from the monosaccharaides fructose and glucose, and has about the same relative sweetness as sucrose. Honey is produced by bees collecting nectar and honeydew for use as sugars consumed to support metabolism of muscle activity during foraging or to be stored as a long-term food supply. During foraging, Bee's access part of the nectar collected to support metabolic activity of flight muscles, with the majority of collected nectar destined for regurgitation, digestion, and storage as honey (Suarez *et al.,* 1996).

We all know that honey has many health benefits. It is, after all, a natural antiseptic and contains anti-fungal properties both of which are believed to be one of the reasons honeys as a root hormone seems to work so well. In fact, just 1 tablespoon (15 ml) of honey is said to contain about 64 calories and 17 grams of carbohydrates, most of which come from sugars, and seems to provide plants with a much-needed

boost just as it does for us. In addition to containing possible rooting agents, it is thought that using honey for cuttings helps guard against bacterial or fungal problems, allowing the little cuttings to remain healthy and strong (Tilley, 2019).

2.4 Effect of different plant hormones on growth and yield of plants

Vijoy and Kumar (2000) found out that 30-day old Cauliflower (cv. Pant Subhra) seedling were transplanted into experimental plots and treated with 50 or 100 ppm GA_3, 5 or 10 ppm IBA, or 100 or 2000 ppm NAA at 15 and 30 days of growth. The results clearly explained that GA_3 produced the tallest plants, the largest curds and the highest curd yields.

In 2003 Kar *et al.* carried out an experiment on the effect of variety and growth regulators on growth and yield of cabbage (Brassica oleracea var. capitata) at the Horticulture Farm of Bangladesh Agricultural University, Mymensingh, Bangladesh during October 2002 March, 2003. The highest gross and marketable yields of cabbage were gained from the plants sprayed with 50 ppm NAA (Naphthalene Acetic Acid).

A field experiment was carried out by Chauhan and Tandel (2009) during the Rabi season at Agronomy farm, N.M. College of Agriculture, Navsari Agricultural University, Navsari. Experiment showed that spray of GA_3 and NAA significantly influenced the performance of growth, yield and quality characters of cabbage. The best plant hormone treatments for growth, yield and quality characters of cabbage was GA_3 100 mg l-1 foliar spray at 30 and 45 days after transplanting followed by NAA 100 mg l-1 foliar spray at 30 and 45 DAT.

A study was carried out by Roy *et al*. (2010) at the Horticulture Farm of Bangladesh Agricultural University, Mymensingh to study the effect of starter solution and GA_3 on growth and yield of cabbage. The two-factor experiment consisted of four levels

of starter solution, viz., 0, 1.0, 1.5 and 2.0% of urea, and four concentrations of GA_3, viz., 0, 25, 50 and 75 ppm. The highest yield (104.93 t/ha) was found from 1.5% starter solution which was significantly different from other solutions, and the lowest yield (66.86 t/ha) was found from the control. Significantly the highest yield (104.66 t/ha) was recorded from the treatment of 50 ppm GA_3, while the lowest yield (66.56 t/ha) was found from control. In case of combined effect, the highest yield of cabbage (121.33 t/ha) was gained from the treatment combination of 1.5% starter solution + 50 ppm GA_3 followed by 1.5% starter solution + 75 ppm GA_3 (115.22 t/ha), while the lowest yield (57.11 t/ha) was produced by the control treatment. Economic analysis found that 1.5% starter solution + 50 ppm GA_3 treatment was the best treatment combination in respect of net return (Tk. 173775/ha) with a benefit cost ratio of 3.52.

Experiment on influence of GA, NAA and CCC at three different concentrations on different growth parameters of cabbage were conducted by Lendve *et al*. (2010) found that application of GA 50 ppm was found significantly superior over most of the treatments in terms of number of the leaves, plant spread, and circumference of stem, left area, fresh and dry weight of the plant, shape index of head, length of root, fresh and dry weight of root. Except treatment GA 75 ppm, gave better results for days required for head initiation and head maturity.

The effect of GA_3 and/or NAA (both at 25, 50, 75 or 100 ppm) on the yield and yield parameters of cabbage (cv. Pride of India) was examined by Dhengle and Bhosale (2008) in the field at Department of Horticulture, college of Agriculture, Parbhani. The highest yield was gained with GA_3 at 50 ppm followed by NAA at 50 ppm (332.01 and 331.06 q/ha, respectively) Combinations and higher concentrations of plant hormones proved less effective.

The experiment was conducted by Roy and Nasiruddin (2011) to study the effect of GA_3 on growth and yield of cabbage. Single factor experiment consisted of four concentrations of GA_3, viz., 0, 25, 50 and 75 ppm. Significantly the minimum number of days to head formation (43.54 days) and maturity (69.95 days) was found with 50 ppm GA_3 and 50 ppm GA_3 gave the highest diameter (23.81 cm) of cabbage head while the lowest diameter (17.89 cm) of cabbage head was found in control condition (0 ppm GA_3) treatment. The application of different concentrations of GA_3 as influenced independently on the growth and yield of cabbage. Significantly the maximum yield (104.66 t/ha) was found from 50 ppm GA_3.

Experiments were carried out by Sharma and Singh (2009) to show the effects of foliar application of gibberellic acid on vegetative growth, flowering, fruiting and various disorders in ‘Chandler’ strawberry. GA_3 (75 ppm) was applied to the strawberry plants either during mid-November (at fruit bud differentiation stage), or mid-February (pre-flowering stage) or at both times. Fruit under control were sprayed with tap water only. Experiment was recorded on vegetative attributes like crown height, crown spread, petiole length, leaf number, leaf area; flowering and fruit set, fruit size; production of albino, malformed and button berries, total yield and marketable fruit yield and quality parameters, like juice content, TSS, ascorbic acid contents, acidity etc. Finding indicated that GA_3 (75 ppm) spray either during mid-November or mid-February or at both times has favorably influenced all vegetative attributes of ‘Chandler’ strawberry over control. Similarly, fruit set was enhanced, and production of malformed and button berries was reduced, but albinism remained unaffected. Although individual berry weight was diminished slightly, but fruit number, total as well as marketable yield was increased tremendously over control with no adverse effect on fruit quality parameters. In all, spraying GA_3 both during mid-November and mid-February was much more effective in achieving the desirable results than single application of GA_3 either during mid-November or mid-February.

An experiment was carried out in December, 2002 by G. Paroussi *et al*., to see the effect of gibberellic acid (GA_3) on the vegetative growth, flowering characteristics and yield of three strawberry cultivars, the June bearing 'Camarosa' and 'Laguna' and the day neutral 'Seascape', was investigated, under heated and unheated greenhouse conditions and under short (10 h) and long (16 h) photoperiod. Young plants, potted in mid-November, were kept outdoors for 1 month, and then sprayed once with GA_3 (0, 50, 200 mg/l) and placed under the different environmental conditions. GA_3 application enhanced petiole length and leaf area of the strawberry plants in most treatments. It diminished the time needed for inflorescence emergence, accelerated flowering and increased the number of flower buds and open flowers in most growing conditions, the effect being greater on 'Seascape' compared to the other cultivars. GA_3 at the lower concentration (50 mg/l) did not affect total marketable yield, whereas at 200 mg/l, combined with long photoperiod, it enhanced the percentage of aborted flowers plus malformed fruits, resulting in a significant decrease in total marketable yield.

In 2011 Choudhury *et al*. was conducted an experiment to assess the effect of different PGRs on tomato during summer season at Horticulture Farm of Sher-e-Bangla Agriculture University, Dhaka-1207. They have revealed the plant in plant growth regulators (PGR) viz. PGR_0 = Control, PGR_1= 4-CPA (4-chloro-phenoxy acetic acid) @ 20 ppm, PGR_2 = GA_3 (gibberellic Acid) @ 20 ppm and PGR_3= 4-CPA + GA_3 @ 20 ppm through foliar application. They have concluded that the growth and yield contributing characters of tomato plants were significantly differed due to different PGR. They have showed the maximum plant height at 60 DAT, number of flowers cluster per plant, number of flowers per plant, number of fruits per plant, maximum individual fruit weight and maximum yield in the treatment PGR_3, and the minimum for all parameters were found in control (PGR_0) treatment.

In 2002 Bhosle *et al.* was carried out an experiment to know the effects of NAA (25, 50 and 75 ppm), gibberellic acid (15, 30 and 45 ppm) and 4-CPA (25, 50 and 75 ppm) on the growth and yield of tomato cultivars Dhanashree and Rajashree through the field experiment carried out in Rahuri, Maharashtra, India during the summer of 1997. They have added that the number of flowers per cluster, fruit weight and marketable yield increased with increasing rates of the plant growth regulators. Treatment with 30 ppm gibberellic acid resulted in the tallest plants, whereas treatment with 25 ppm 4-CPA and 45 ppm gibberellic acid resulted in the highest number of primary branches of Dhanashree (4.16) and Rajashree (5.38), respectively. The highest marketable yield of Dhanashree and Rajashree resulted from treatment with 75 ppm 4-CPA.

2.5 Relation between different plant hormones on yield of plants

In 2001 Wang, Q.M. and Q.M. Wang carried out an experiment on the effect of CPPU (for chlorfenuron) application on growth and endogenous phytohormones contents of M. charantia cv. Kaihua Changbai was determined. Application of CPPU to the ovary within the concentration of 10-50 mg/liter to accelerated fruit growth by increasing the length, diameter and fresh weight of fruits, while 100 mg/liter inhibited fruit growth. HPLC analysis found that the endogenous ZT (zeatin) content of fruit was lowered and the endogenous ABA (Abscisic acid) content was improved by CPPU treatments at the concentration of 20 and 100 mg/liter, and that the endogenous contents of IAA and GA_3 (gibberellic acid) were significantly improved by application of CPPU at 20 mg/liters, reaching a peak value 6 days after anthesis.

Fabiana Csukasi *et al.*, (2011) carried out an experiment to observe gibberellins biosynthesis and signaling during development of the strawberry receptacle. The result indicated enlargement of receptacle cells during strawberry (*Fragaria* × *ananassa*) fruit development is an important factor determining fruit size, with the

increase in cell expansion being one of the most important physiological processes regulated by the plant hormone gibberellins (GA) studied the role of GA during strawberry fruit development by analyzing the endogenous content of bioactive GAs and the expression of key components of GA signaling and metabolism. Bioactive GA_1, GA_3 and GA_4 were observed during fruit development, with the content of GA_4 being extremely high in the receptacle, peaking at the white stage of development.

An experiment to study the impact of various chemicals (Ethrel, NAA, Cycocel, MH, PCPA, Ascorbic acid and Boron) on the growth, flowering and yield of bitter gourd was conducted. PCPA at 100 ppm improved plant growth significantly. The treatment of CCC at 250 and 500 ppm produced female flowers about 12 days earlier in comparison to control plant. Highest fruit yield per plant (3123 g) was produced under Cycocel 250 ppm followed by Ascorbic acid 25 ppm and Cycocel 250 ppm (Mangal *et al*., 1981).

In 2013 Baliyan *et al*. was carried out an experiment to show the effects of different concentrations of 4-chlorophenoxyacetic acid (4-CPA) plant hormone on fruit set, yield and economic benefit of tomato (*Lycopersicon esculentum* Mill) growing in high temperatures in Botswana (Southern Africa). In a field experiment laid under complete randomized block design, tomatoes flowers were treated with four different concentrations of 00 ppm (control), 15 ppm, 45 ppm and 75 ppm of 4-CPA growth regulator. Data collection engaged number of fruit set, weight of small tomato, weight of cracked tomatoes, weight of cat face tomatoes, weight of rotten tomatoes, weight of pest damaged and marketable tomatoes. A two-way analysis of variance (ANOVA) was accomplished using the SPSS software ver.19 to analyze the data. The application of 4-CPA hormone showed a positive and significant effect on the fruit set and yields of tomato. A positive relationship between the growth regulator concentration and the fruit set as well as total yield of tomato was also

established (higher the concentration, higher the fruit set and tomato yield). The 75-ppm concentration of 4-CPA resulted not only the maximum increase in fruit set but also increased the tomato yield and hence economic benefit in tomato production increased. It was added that use of 4-CPA hormone increased the fruit set, yield and economic benefit of summer tomato production. Suggested future research can be carried out to observe the effect of higher concentration of the 4-CPA hormone on fruit set, yield and fruit quality of tomatoes.

Sasaki *et al*. (2005) was carried out a field experiment on decreased of high temperature inhibition in tomato fruit set by plant growth regulators. They trialed the effect of plant growth regulators on fruit set of tomato (*Lycopersicon esculentu*m Mill.) under high temperature and in a controlled environment in the field under rain shelter. Tomato plants expounded to high temperature (34/20 ^{0}C) had reduced fruit set. Treatments of plant growth regulators decreased the fruit set inhibition by high temperature to some extent, especially treatment with mixture of 4-chlorophenoxy acetic acid (4-CPA) and gibberellins (Gas). They have found, in the field experiment, tomato treated with a mixture of 4-CPA and Gas showed increased fruit set and the number of normal fruits (excluding abnormal types such as puffy fruit) were more than the plants treated with 4-CPA alone during summer.

2.6 Different plant hormones effect on flowering and yield of plants

In 1999 Das and Rabhal reported that in a greenhouse experiment on cucumber cultivars Chinese green, Pusa Sanyog and Poinsette, NAA was applied at 30 ppm or 100 ppm, kinetin at 10 ppm or 50 ppm and Ethrel at 250 ppm or 500 ppm at the 4 to 5 leaf stage and at flower bud emergence. NAA application produced the largest fruits with the highest flesh: placenta ratio. TSS and ascorbic acid content were highest when Ethrel was applied.

Gedam *et al.* (1998) carried out an experiment on bitter gourd plants treated with 15 ppm, 25 ppm or 35 ppm GA_3 50 ppm or 150 ppm NAA, 50 ppm, 150 ppm ethephon, 100 ppm, 200 ppm or 300 ppm maleic hydrazide, 2 ppm, 4 ppm or 6 ppm boron or with water (control). GA_3 at 35 ppm produced the earliest male flower and NAA at 50 ppm evolved the earliest female flower. Fruit maturity was earliest in plants treated with 50 ppm NAA or 4 ppm boron.

Arora *et al.* in 1994 found out that flower application of plant growth regulator had significant effect on growth, flowering and yield of long melon. The experiment was carried out during the summer seasons of 1991 and 1992 to study the effect of ethephon, GA_3 maleic hydrazide (MH), and NAA on melon. Growth regulators were applied at the 2-and 4-leaf stages. GA at 25 mg/liter resulted in the longest vine length (3.97 m), whereas vine length in controls (water sprayed) was 2.82 m. Ethephon at 250 mg/liter resulted in the highest number of branches/plant (10.8), shortest internode length (8 cm), lowest male: female flower ratio (3.1), fewest days to first female flower (68 days), maximum number of female flower/plant (27) and fruits /plant (17.7) and maximum plant yield (1.36 kg/plant). Ethephon at 250 mg/liter also gave the highest fruit yield/ha (29.76 t), while GA at 25 mg/liter gave the lowest (11.08 t).

A study was carried out by Ouzounidou *et al.* (2010) at the Institute of Food Technology, National Agricultural Research Foundation, Lycovrissi, Greece to study the pre- and post-harvest physiology and quality responses of green pepper (*Capsicum annuum* L. cv 'Standar p.13/0211003-01-Agris') on exogenous Gibberellic acid-GA3 (100 μM), Prohexadione-Calcium (100 mg l-1), Cycocel (100 mg l-1) and Ethephon (100 mg l-1) applied as foliar sprays, were investigated. Among PGRs, GA_3 @ 100μM was effective in promoting flowering and better for vegetative characteristics.

Synthetic plant growth regulators (PGRs) such as 4 –chlorophenoxyacetic acid (4- CPA) now used commercially in Korea, Japan and China are known to impact on fruit setting in tomatoes. These are applied at 50 mg/liter as a spray on flower cluster when they are in blossom. Spraying is usually done on each cluster at 7 to 14 days interval. It is asserted that, the treatment increase fruit set and fruit size and induces early yield. However, it may cause puffy fruits at high concentration or under high temperatures (AVRDC, 1990).

To study the impact of ethrel (ethephon), GA_3 and uniconazole on strawberry plants an experiment was conducted by El-Shabasi *et al*., (2008). The results indicated that GA_3 application enhanced plant petiole.GA_3, ethrel and uniconazole increased total carbohydrate percentage in the foliage of strawberry plants. GA_3 at 10 ppm or ethrel at 250 ppm enhanced the number of flowers and total yield.

In 1999 Al-Masoum and Al-Masri found that Cucumber was grown in a greenhouse in 1996-97 and ethephon applied at 250 ppm, 350 ppm and 450 ppm at the seedling stage (2-4 true leaves). Data were culled on the total yield, early yield, late yield, number of female flowers, number of male flowers, days to the first male flowers, days to first female flowers, number of nodes to the first female flower, number of nodes to the first male flower and plant height. All the cases positive result was obtained from ethephon treated plants. Ethephon persuaded femaleness (pistillate flowers) on the main stem that led to greater fruit production.

2.7 Plant hormones effect on leaf and yield measure of plants

In 2010 Yu *et al*. carried out an experiment with '8398' cabbage (*Brassica oleracea* var. captata L.) plants with 7 true leaves and 'Jingfeng No. 1' cabbage plants with 9 true leaves were vernalized in incubator. Then, '8398' cabbage plants vernalized for 18 days and 'Jingfeng No. 1' cabbage plants vernalized for 21 days were treated by high temperature of 37^0C for 12 hours to explore the changes of endogenous growth regulator during de-vernalization in cabbage. The findings showed that: GA_3 content had less changes, IAA content rose and ABA content decreased during de-vernalization. Compared with CK (vernalization period), GA_3 and ABA content diminished significantly, whereas IAA content rose significantly when de-vernalization ended. Lower GA_3 and ABA content, and higher IAA content can benefit the accomplishment of de-vernalization.

2.8 Relation of different plant hormones on rooting of plants

In 2016 Osman Topaçoğlu, Hakan Sevik, Kerim Güney and Cetin Unal conducted an experiment on effect of rooting hormones on the rooting capability of *Ficus benjamina L.* cuttings, to find the most frequently vegetative propagation method is the rooting of the stem cuttings in various media such as, pearlite, peat, sand, through exposure to high-concentration rooting hormones (IBA, IAA, NAA, etc.). 39 different treatments were conducted, and their results were evaluated. Sand and perlite were taken as solid rooting media. Stem cuttings were kept in low-concentration hormones abidingly after cutting (liquid medium). In this way, their rooting capability was examined. Rooting trials were carried out before stem cuttings were taken to solid rooting media. As conclusions, the highest rooting ratio was founded for 10 ppm of NAA (94.43%) and 100 ppm of IBA (93.9%) in liquid media. Moreover, the highest root length and the average root length were quite low in liquid media.

In a field experiment conducted by Wang *et al*. (2004), the effects of different growth regulators and substrates were studied. The regulators applied were NAA, ABT (Amino Benzotriazole) root-promoting powder, and IBA applied at 1000, 1500, and 2000 mg/liter. Water was used as control. The survival rate for cuttings and plant quality increased significantly with 1000 and 1500 mg NAA/liter. ABT treatment at 1500 mg/liter did not increased survival rate, but increased plant quality. Plant height, number of leaves, leaf area, root length, fresh leaf weight, fresh root weight, dry leaf weight, and dry root weight improved by 47.46, 35.42, 193.92, 235.79, 89.90, 40.51, 40.79, and 53.44 percent respectively, as compared with the control.

2.9 Relation of different plant hormones on other characteristics of plants

Ana *et al.* in 2002 experiment on 'Could plant hormones be the basis of maturation indices in *Pinus radiata*?' and found that maturation and phase change in woody plants are developmental processes at present poorly understood, especially from a physiological point of view. Maturation indices, such as plant hormones, could be used to understand more about the events that accompany the increase in the developmental state and to choose optimal conditions in order to improve forest programs and make them more profitable. In order to determine this putative index, the contents in Abscisic acid-like substances (ABA-like), indole-3-acetic acid (IAA) and several Cytokinins (Cks) were analyzed in terminal and axillary buds of *Pinus radiata* trees with different developmental condition to compare their phytohormonal status. An increase in the content of some zeatin-type (Z-type) Cks, and a decrease in isopentenyladenine-type (iP-type) Cks levels throughout maturation were shown both in terminal and axillary buds. This fact showed us to consider the ratio iP-type/Z-type Cks, which diminished in parallel with the increasing developmental state of the tree, as a maturation index.

The in vitro propagation of shoot tips and the quality of explants of cabbage were significantly affected by various concentrations of BA and NAA in the culture media reported by Liao *et al*. (2003). A higher rate of shoot proliferation with better quality plantlets were gained when the medium contained more than 0.8 mg BA/liter and less than 0.5 mg NAA/liter. The effects of kinetin and zeatin on propagation efficiency were better than the combination of both treatments when applied in similar concentrations. Heat shock treatment (45^0 for 2 hour) stimulated the proliferation of shoots.

CHAPTER III

MATERIALS AND METHOD

The experiment was conducted during the period from April 2019 to September 2019 to study the response of Moringa cuttings in different plant growth regulators. This chapter includes a brief description of the location of experimental site, soil and climate condition, materials used for the experiment, experimental design, data collection procedure and procedure of data analysis that were used for conducting the experiment**.**

3.1 Experimental site

The experiment was conducted at the Agroforestry Farm of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh. The location of the study site is situated in $23^0 74^/$N latitude and $90^0 35^/$E longitude (Anon, 1989). The altitude of the location was 8 m from the sea level (The Meteorological Department of Bangladesh, Agargaon, Dhaka).

3.2 Characteristics of soil

The soil of the experiment collected from Amin Bazar; Dhaka belongs to the Madhapur Tract (UNDP, 1988) under AEZ No. 28. Poly bag were filled with soil and cow dung. The characteristics of the soil used in this experiment were analyzed in the Soil Testing Laboratory, SRDI, Farmgate, Dhaka and details soil characteristics are presented in Appendix I.

3.3 Climatic condition of the experimental site

The experimental site was under the subtropical climate, characterized by three distinct seasons, winter season from November to February and the pre-monsoon or hot season from March to April and the monsoon period from May to October (Edris *et al*., 1979).

3.4 Planting materials

Moringa stem cutting were used as propagating materials. Stem cuttings were collected from the Agroforestry Farm Laboratory, SAU, Dhaka-1207. All the cuttings were collected from same mother plant. The length of all cuttings were 3 feet. Cuttings were 5 cm in diameter. Age of the cuttings were around 1-1.5 years.

3.5 Treatments of the experiment

There were five treatments in the experiment. Those are listed below:

Treatment No.	Composition
T_1	Honey
T_2	Rooton Hormone
T_3	Auxin
T_4	Cutting Hormone
T_5	Water (Control)

According to manufactures recommendation and previous research report Auxin used as 0.01 ppm, Rooton Hormone used 100 g per poly bag, honey used as raw solution and Cutting Hormone are used as paste.

3.6 Design and layout of the experiment

The experiment was laid out in a Completely Randomized Design (CRD) with eight replications. The experiment was conducted in poly bag. A Total of 40 poly bags were prepared to conduct the experiment. Three cuttings from each replication were randomly selected for data collection.

3.7 Poly bag preparation

Poly bag were prepared with soil and cow dung mixture. Ratio of soil and cow dung is 4:1 (v/v) (Rufai, *et al.* 2016). Cow dung were collected from SAU farm. Dry and granular cow dung mixed with soil and kept for 24 hours than filled into poly bag. Average poly bag soil weight was 7 kg.

3.8 Application of phytohormones

Auxin collected from Bokhshi Bazar. Honey (Mustard) were collected from Sirajganj. Rooton hormone (NAA, National Agricare) and Cutting hormone collected from Krishibid Upokoron nursery, Agargaon, Dhaka-1207.

3.8.1 Preparation of IAA

At first 1 g of Indole-3-Acetic Acid was taken into a 100 ml volumetric flask adding with 5 ml Ethyl Alcohol (C_2H_5OH) to dissolve the powder and the volume was made up to the mark with distilled water. Agitation was done to dissolve the powder. The concentration of the stock solution was 10 ppm and finally the concentration of the working solution was 0.01 ppm. Working solution was made with 5 ml of stock solution diluted with 500 ml distilled water (Gold Biotechnology, 2019).

3.8.2 Preparation of Cutting hormone

Cutting hormone was used in the form of paste. Cutting hormone solution was prepared by adding water then hormone was pasted onto cut part of the stem cutting of Moringa, which was used as experimental materials.

3.8.3 Preparation of Rooton hormone

Rooton hormone (NAA) was mixed into growing media before Moringa cutting planting. It mixed with growing media before poly bag preparation. A total of 100 g Rooton hormone was mixed into the growing media of each poly bag. After 24

hours of soil mixing with cow dung, Rooton hormone was added into growing media very carefully. After that stem cutting were transplanted immediately.

3.8.4 Preparation of honey as a growth hormone

Pure honey was used as raw solution. Before transplanting, planting part of stem cuttings was soaked into honey for 3 min then air dried for 5 min. Then it transplanted carefully so that soaked part was not touched anything.

3.9 Transplanting stem cutting

Healthy and uniform moringa stem above 1 year old with 5-6 leaves were selected as planting material. Stem cutting was 5 cm in diameter. Stem cutting are transplanted in the experimental poly bags on 1 May, 2019. The stem cuttings are cut with sharp tool for minimizing harm. Transplanting was done in the afternoon. The cuttings were watered immediately after transplanting.

3.10 Intercultural operations

After transplanting, various intercultural operations, such as weeding, irrigation, pest and disease control, etc. were performed for better growth and development of the moringa stem cuttings.

3.10.1 Weeding

The hand weeding was done 15, 30 and 45, 60 days after transplanting of stem cuttings to keep the poly bags free from weeds.

3.10.2 Irrigation

Mild watering was given by a watering cane at every morning and afternoon. Following transplanting and it was followed for a week for rapid and well

establishment of the transplanted seedlings. After that watering given when it was needed.

3.10.3 Pest and disease management

Insect infestation was a serious problem in the period of establishment of plants in the field. Sevin (Group: 85-curbaril, Company: Bayer company) used for control ant. It mixed with soil in the time of soil preparation. Furadon 5G (Group: Carbofuran, Company: Podma oil company) used to prevent soil born disease. It also mixed with soil in the time of soil preparation.

3.11 Data collection

Data was collected from three cuttings from each treatment randomly and average data were used for showing difference for each plant hormones. Data were collected in respect of the following parameters to measure plant growth.

3.11.1 Number of buds per plant

Bud number of each cuttings were counted fourth time in total duration. In the period of 15, 30, 45, 60 DAT (days after transplanting) of data collection to see progress of vegetative growth and bud number.

3.11.2 Number of branches per plant

The total number of branches per plant was counted from each selected plant of moringa. Data were recorded as the average of 3 plants selected at random at final harvest.

3.11.3 Number of leaves per plant

The total number of leaves per plant was counted from each selected plant. Data were recorded as the average of 3 plants selected at random from each treatment.

3.11.4 Length of leaves

Three leaves length were counted randomly from each plant. Data were recorded as the average of leaves from 3 plants in centimeter (cm) of each treatment.

3.11.5 Length of leaves base

Three leaves base length were counted randomly from each plant. Data were recorded as the average of leaves bases from 3 plants in centimeter (cm) of each treatment.

3.11.6 Length of third internode from top

Lengths of third internode were counted randomly from each plant. Data were recorded as the average from 3 plants in centimeter (cm) of each treatment.

3.11.7 Number of rachilas per leaves

The total number of rachilas per leaf was counted from each selected plant randomly. Data were recorded as the average of 3 plants selected at random from each treatment.

3.11.8 Number of leaflets per leaves

The total number of leaflets per leaf was counted from each selected plant. Data were recorded as the average of 3 plants selected at random from each treatment.

3.11.9 Number of roots per plant

The total number of roots per plant was counted from each selected plant. Data were recorded as the average of 3 plants selected at random from each treatment.

3.11.10 Length of root

The length of roots per plant was counted from each selected plant. Data were recorded as the average of 3 plants selected at random from each treatment.

3.11.11 Fresh weight of root

Weight of total number of roots of the plant was weighted. Data were recorded from five plants randomly selected from each treatment.

3.11.12 Dry weight of root

After oven dry, weight of total number of roots is weighted. Data were recorded from five plants randomly selected from each treatment.

3.11.13 Fresh weight of shoot

Data were recorded from five randomly selected plants of each treatment. Total shoot weight of each selected plant except cutting stem was weighted by using balance (Digital weight machine, Labtex, bangladesh)

3.11.14 Dry weight of shoot

Data on shoot weight were recorded from randomly taken three plants from each treatment. After oven (Digital GSM Weight Balance Machine, India) dry, weight of total vegetation except cutting stem is weighted.

3.12 Statistical analysis

All the data were analyzed for variance (ANOVA) and tested for significance using Least Significant Difference (LSD) using R-3.5.1 software (R Core Team, 2017).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to determine the response of Moringa in response to plant growth regulators. To select the best phytohormone data on vegetative characters were recorded. A summary of the analysis of variance (ANOVA) of the data on different characters have been presented in Appendix II-XVIII. The analytical results and their possible interpretations were given under the following sub-headings:

4.1 Results

4.1.1 Number of buds per plant

Moringa showed significant variation on bud formation for different plant growth regulators (Table 1, Appendix II-V). Bud number were counted at 15, 30, 45, 60 DAT. The significantly highest number of buds (3.00) were recorded at 15 DAT with T_2 treatment where the lowest number of buds (0.67) were recorded in the plant treated with T_4. T_1 showed statistically similar result (2.67) as T_2 closely followed by T_3 and T_4 (2.33, 1.33 respectively). The highest (4.33) and lowest (1.33) bud number found in both 30 and 45 DAT with T_1 and T_4 respectively. But in 60 DAT the significantly highest bud number (6.67) was found with T_1 and the least bud number (1.67) observed in plants treated with T_4. Where T_2 showed statistically similar result (6.00) as T_1. Here T_3 and T_5 showed the least performance with the value of 3.00 and 2.33 respectively.

Table 1. Effect of different phytohormones on bud formation of Moringa cuttings at different day after transplanting (DAT)

Treatment	Number of Bud/cutting			
	15 DAT	**30 DAT**	**45 DAT**	**60 DAT**
T_1	2.67 a	**4.33 a**	**4.33 a**	**6.67 a**
T_2	**3.00 a**	**4.33 a**	**4.33 a**	6.00 a
T_3	2.33 a	3.00 b	3.00 b	4.66 b
T_4	0.67 b	1.33 c	1.33 c	1.67 d
T_5	1.333 b	2.33 bc	2.33 bc	3.00 c
$LSD_{(0.01)}$	0.94	1.24	1.24	0.81
Level of Significance	**	**	**	**

T_1= Honey, T_2= Rooton H, T_3= Auxin, T_4= Cutting H, T_5= Water (control).

4.1.2 Number of branches per plant

Different plant hormones impact significant variation on number of branches on Moringa (Table 2, Appendix VI). At final stage T_1 showed the significantly highest number of branch (6.67) per plant. And the lowest number of branches found with T_4 (1.67). Other treatments also showed mix performance. T_2 (6.00) and T_3 (4.67) gave better performance than T_4 (1.67) and T_5 (3.00).

Table 2. Effect of different phytohormones on formation of branch of Moringa cuttings after 60 days

Treatment	Number of branches
T_1	**6.67 a**
T_2	6.00 a
T_3	4.67 b
T_4	1.67 d
T_5	3.00 c
$LSD_{(0.01)}$	0.81
Level of Significance	**

T_1= Honey, T_2= Rooton H, T_3= Auxin, T_4= Cutting H, T_5= Water (control).

4.1.3 Number of leaves per plant

Moringa showed significant variation on number of leaves per plant for different plant hormones (Figure 1, Appendix VII). Phytohormones trigger initial growth of stem cutting that helps to produce more leaves. Here T_1 produced maximum number of leaves (53.67) for moringa and T_4 produced lowest number of moringa leaves (13.67). Other plant hormones of the experiment showed mix impact. Here T_2 (49.67) showed better performance than T_3 (37) and T_5 (25) respectively.

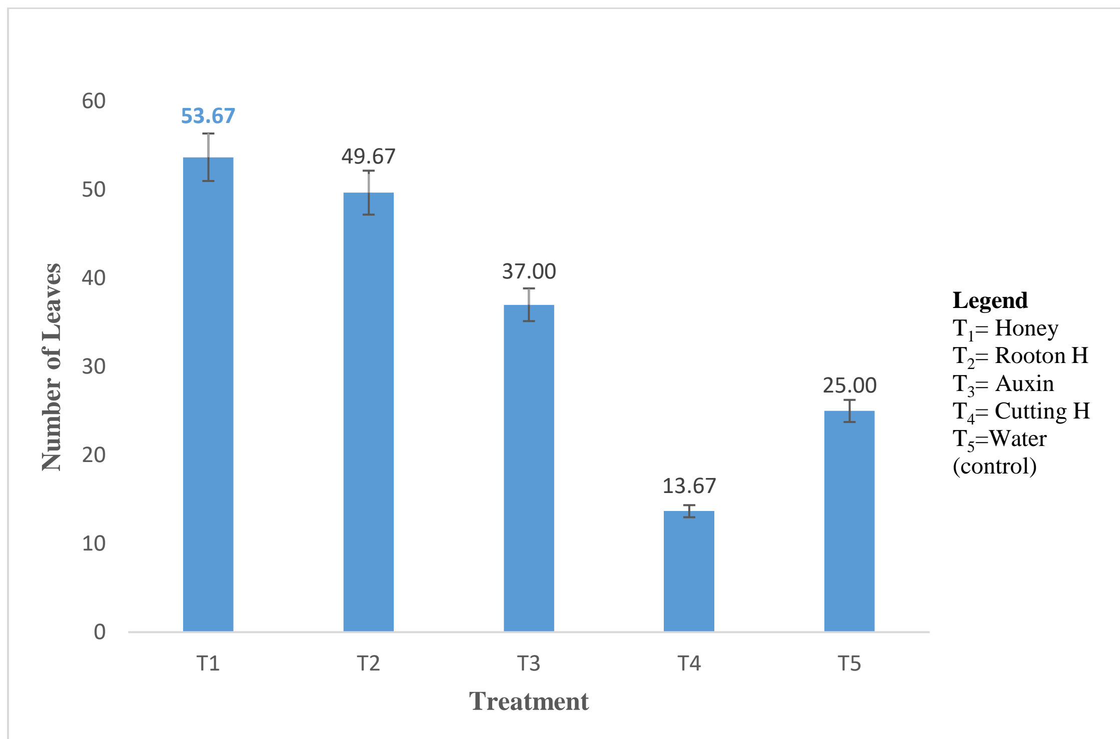

Figure 1. Effect of different phytohormones on number of leaves formation per Moringa cuttings

4.1.4 Leaf length

Moringa cuttings showed significant variation for leaf length (Table 3, Appendix VIII). Leaf length showed vegetative growth and leaf yield. Here T_1 showed the significantly highest value (71 cm) and the lowest length (44.67 cm) of leaf length was observed in plant treated with T_4. And other plant hormones also showed significant variation. Here, this experiment T_2 (53.33 cm) gave superior results then T_3 (48.67 cm) and T_5 (47.67 cm) respectively.

4.1.5 Leaf base length

Leaf base length indicate leaf characteristics that the effect of vegetative growth showed significant results with different phytohormones (Table 3, Appendix IX). Here, treatment T_4 gave the lowest average leaf base length (10.33 cm) for moringa and the significantly highest leaf base length was observed in T_1 (15.33 cm). T_2 (13.67 cm) treatment gave superior result than T_3 (10.67 cm) and T_5 (11.00 cm) respectively.

Table 3. Effect of different phytohormones on average leaf and leaf base length of Moringa cuttings

Treatment	Average leaf length (cm)	Average leaf base length (cm)
T_1	**71.00 a**	**15.33 a**
T_2	53.33 b	13.67 a
T_3	48.67 b	10.67 b
T_4	44.67 b	10.33 b
T_5	47.67 b	11.00 a
$LSD_{(0.01)}$	9.46	1.69
Level of Significance	**	**

T_1= Honey, T_2= Rooton H, T_3= Auxin, T_4= Cutting H, T_5= Water (control).

4.1.6 Length of third internode from top

There also significant variation on third internode length from top of leaves (Figure 2, Appendix X). The significant highest average length of third internode of leaf from top produced by T_1 (9.60 cm) and the lowest length (7.57 cm) of third internode of leaf from top was produced by the plant treated with T_4. Others plant hormones showed variation of results on average length of third internode of leaves from top. Treatment T_2 (9.27 cm) gave better performance than T_3 (8.40 cm) and T_5 (7.73 cm) respectively.

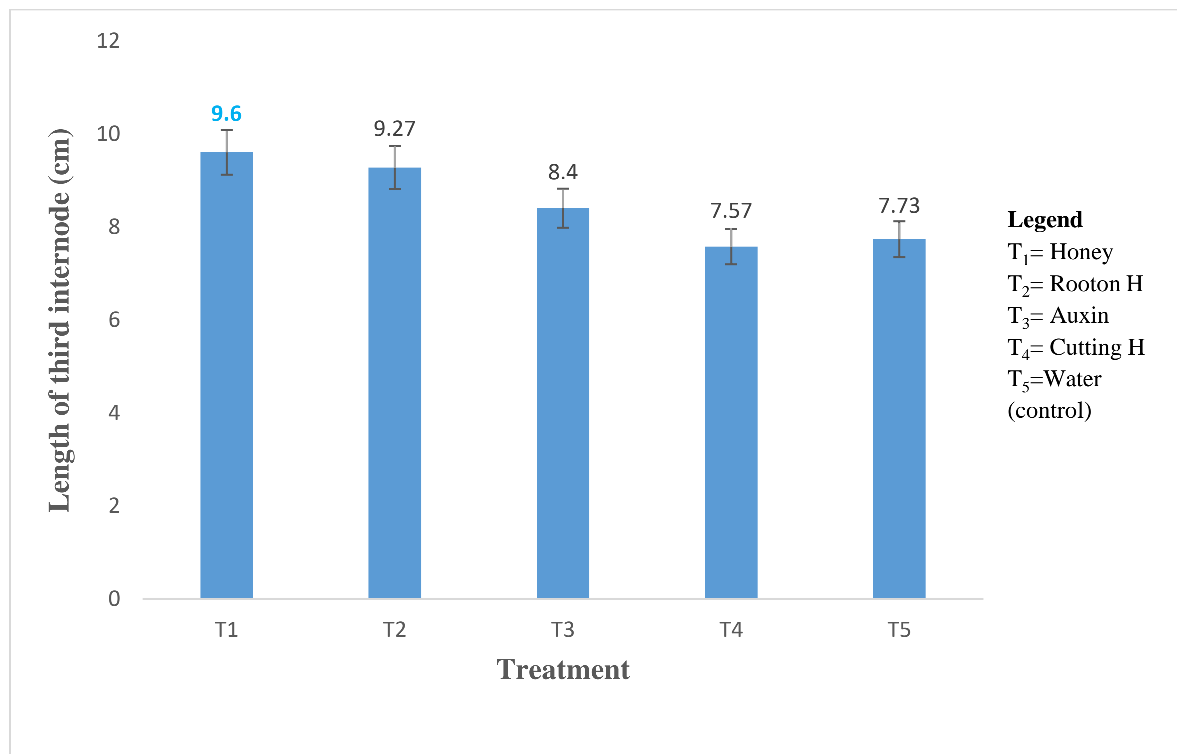

Figure 2. Effect of different phytohormones on length of third internode of the leaf from top of Moringa cuttings

4.1.7 Number of rachilas

Moringa cuttings had also showed significant results on number of rachilas per leaf (Table 4, Appendix XI). Against different treatment number of rachilas effect on number of leaflets, effect on total volume of leaf and at the end reflects vegetative growth of the plant. Though difference between different hormones is very low but also the highest (17.33) number of rachilas was produced by T_1 and the lowest number of rachilas (14) formed by the plant treated with T_4 treatment. Here, treatment T_2 (16) gave better result than T_3 (15.33) and T_5 (14.33) respectively.

4.1.8 Leaflet number per leaf

Leaflet number showed significant variation when Moringa cuttings were treated with different plant hormones effect on Moringa cuttings (Table 4, Appendix XII). The significantly highest average number of leaflets found in T_4 (398.67) and the lowest number of leaflet (331.67) per leaf was found in plant treated with T_1 treatment. Other plant hormones T_2 (344.67), T_3 (361) and T_5 (381.33) also showed significant difference in results.

Table 4. Effect of different phytohormones on formation of number of rachilas and leaflets per leaf of Moringa cuttings

Treatment	Number of rachilas per leaf	Number of leaflets per leaf
T_1	**17.33 a**	331.67 c
T_2	16.00 ab	344.67 c
T_3	15.33 bc	361.00 bc
T_4	14.00 c	**398.67 a**
T_5	14.33 c	381.33 ab
LSD $_{(0.01)}$	1.41	35.14
Level of Significance	**	**

T_1= Honey, T_2= Rooton H, T_3= Auxin, T_4= Cutting H, T_5= Water (control).

4.1.9 Number of roots

Moringa cuttings showed significant variation on root number for different plant hormones (Figure 3, Appendix XIII). T_1 (20.33) produced the highest number of roots per plant and the lowest number of root (9.33) was formed with T_4. The treatment T_2 (18.67) showed better result than T_3 (14.67) and T_5 (13) respectively.

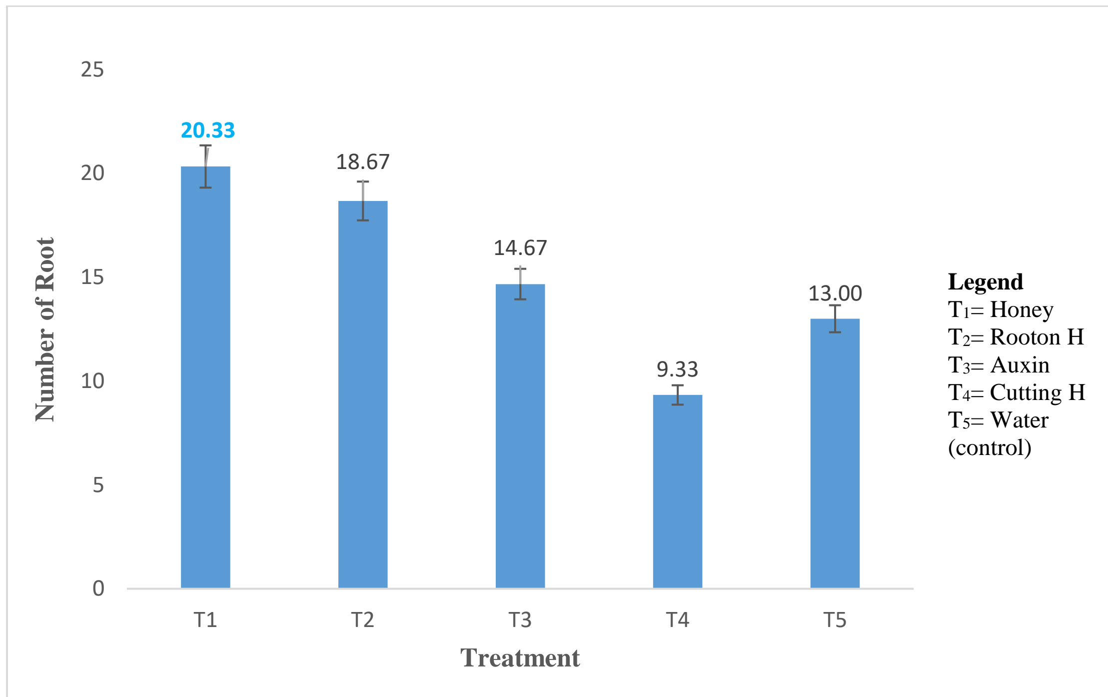

Figure 3. Effect of different phytohormones on root number per plant of Moringa cuttings

4.1.10 Length of root

Moringa cuttings showed significant variation for root length for different plant hormones (Table 5, Appendix XIV). It indicates nutrition supply system which defers vegetative growth and ultimate yield. Treatment T_1 showed the significantly highest length (18 cm) for moringa and the lowest root length (9.33 cm) formed by the plant treated with treatment T_4. Treatment T_2 (15.33 cm) also showed better performance and T_3 (12.67 cm) and T_5 (11.33 cm) showed statistically similar results.

4.1.11 Fresh weight of roots

Moringa cuttings showed significant variation for fresh weight of roots per plant (Table 5, Appendix XV). In this experiment the significantly highest fresh weight of roots (26.24 g) per plant was found with T_1 and the lowest fresh root weight (9.01 g) was found by the plant treated with T_4 treatment. The treatment T_2, T_3 and T_5 showed fresh weight of roots result was 20.61 g, 14.10 g and 12.33 g per plant respectively.

Table 5. Effect of different phytohormones on length and fresh weight of root per plant of Moringa cuttings

Treatment	Length of roots (cm)	Fresh weight of root (g)
T_1	**18.00 a**	**26.24 a**
T_2	15.33 b	20.61 b
T_3	12.67 c	14.10 c
T_4	9.33 e	9.01 d
T_5	11.33 d	12.33 c
LSD $_{(0.01)}$	1.24	2.38
Level of Significance	**	**

T_1= Honey, T_2= Rooton H, T_3= Auxin, T_4= Cutting H, T_5= Water (control).

4.1.12 Fresh weight of shoot

Moringa cuttings showed significant variation for fresh weight of shoot per plant (Figure 4, Appendix XVI). Fresh weight of shoot defines the total volume of vegetative growth of the plant. For the experiment weight of stem cutting ignore for measuring genuine vegetative growth after transplanting. From the result significantly highest fresh weight (730.51 g) of shoot per plant was found with T_1 treatment and the lowest result (149.11 g) was found by the plant which treated with T_4 treatment. T_2 (600.01 g) followed by treatment T_1, second highest result of the experiment. T_3 (469.05 g) gave better result than T_5 (247.74 g).

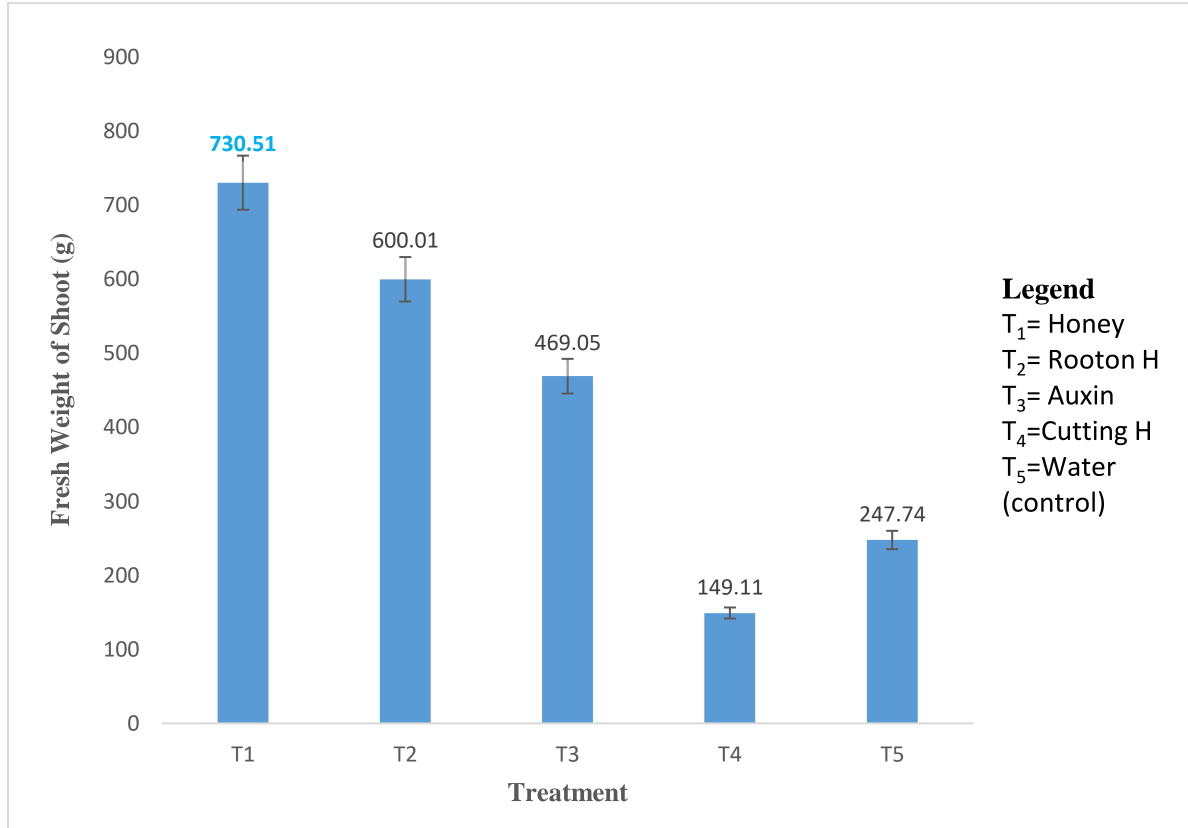

Figure 4. Effect of different phytohormones on fresh weight gaining of shoot per plant of Moringa cuttings

4.1.13 Dry weight of root

In term of dry weight, Moringa cuttings showed significant variation for dry weight of roots (Table 6, Appendix XVII). The significantly highest amount of dry weight (5.98 g) of root was found with T_1 treatment and the lowest amount of dry weight (2.10 g) was found by the plant which treated with T_4 treatment. T_2 (4.66 g) showed better result than T_3 (3.20 g) and T_5 (2.80 g) respectively.

4.1.14 Dry weight of shoot

Moringa cuttings showed significant variation on dry weight of shoot for different plant hormones (Table 6, Appendix XVIII). From the result it was observed that the significantly highest dry weight of shoot was produced in T_1 (158.07 g). The lowest dry weight of shoot was found by the plant which was treated with T_4 (33.76 g) treatment. The treatment T_2 (121.80 g) had better result than T_3 (96.68 g) and T_5 (53.65 g) respectively.

Table 6. Effect of different phytohormones on dry weight gaining of root and shoot per plant of Moringa cuttings

Treatment	Dry weight of root (g)	Dry weight of shoot (g)
T_1	**5.98 a**	**158.07 a**
T_2	4.66 b	121.80 b
T_3	3.20 c	96.68 c
T_4	2.10 d	33.76 d
T_5	2.80 c	53.65 c
$LSD_{(0.01)}$	0.53	15.06
Level of Significance	**	**

T_1= Honey, T_2= Rooton H, T_3= Auxin, T_4= Cutting H, T_5= Water (control).

4.2 Discussion

The growth and development of all plants is controlled by the interaction of two sets of internal factors- nutrition and hormone. The determination of the role played by growth hormones is an essential step towards a successful conduct of the vegetative propagation. The plant growth regulators facilitated the generation of true-to-type, disease free, and high value nursery plants. In this experiment Honey, Rooton hormone, Auxin and Cutting hormone were used to observed their effect on root and shoot development in Moringa cuttings compare to control (without phytohormones) treatment. The treatment Honey showed the superior performance with maximum growth and development parameters (number of buds, leaves, branch, roots per plant; length of roots and leaves; fresh and dry weight of shoot and roots per plant) than others. Where Rooton hormone followed honey and showed better result from remaining treatments.

Honey gave fermented carbohydrates nutrient to Moringa cuttings, that helped initial growth. Might be due to this the Honey produced maximum number leaves (53.67), branch (6.67) per cuttings. Though Rooton hormone gave maximum buds (3) in 15 DAT per cuttings in the early establishment period, after that Honey gradually increase its performance and at the end of the experiment significant difference was found with Rooton hormones results. Maximum roots (20.33) per plant was found in treatment T_1 (Honey). Here, statistically similar result (18.67) was found only from treatment T_2 (Rooton hormone). Even though it is an established fact that employing the utilization of an external hormone is a beneficial process in vegetative production as it stimulates the production of increased root number and a corresponding root elongation (Baul *et al.* 2008, Majeed *et al.* 2009).

Related to this experiment other stem cuttings research trial conducted with Auxin with the aim of enhancing the rooting production and development but discovering, based on results obtained, Auxin having a non-significant influence (Ofori *et al.*

1996, Oni and Ojo 2002, Akinyele 2010). This development could be linked to the understanding that the moringa tree has been found to be enriched with secondary metabolites (Mooza *et al.* 2014), this could probably have played a role in enhancing the rooting process resulting in the non-significant influence of the Auxin.

In this experiment, the utilization of plant growth regulators resulted in a significant root growth and shoot establishment. Hartman *et al.* (1990) observed that the maintenance or presence of leaves on softwood cuttings influenced rooting and shoot survival due to their ability to produce Auxins and carbohydrates. Garner (1944) observed that the high carbohydrate content of softwood cuttings, with low soluble nitrogen, favored rooting. Our softwood stem-cuttings prepared for planting had no leaves. Thus, their dependence on photosynthetic activity for rooting and bud formation was denied, which adversely influenced their sprouting. But we used external plant growth regulator with leaves free stem cuttings.

Hartman *et al.* (1990) reported that cuttings depended on stored food supplies to nourish their developing shoots and roots until the plant became self-sustaining. Hormones influence the rooting of cuttings due to their ability to convert carbohydrate reserves into soluble sugars, which are necessary for cell division and proliferation (Hartman *et al.,* 1990). Mehrabani *et al.* (2016) also reported that the immediate formation and the subsequent growth of roots are the most influential factors affecting the survival of cuttings. Honey as a source of carbohydrates trigger the growth of the cuttings. So vegetative establishment observed higher in Honey than others. In this experiment Honey showed best performance to establish the cuttings to initiate early growth and development of the Moringa cuttings. Oluwagbenga *et al.* (2016) studied an experiment to observe effect of alternative hormones on the rootability of *Parkia biglobosa* and found same result as this experiment. Here, honey gives better performance than control treatment on root length, number of root and longest root of *Parkia biglobosa*.

Due to better initial establishment Honey gave the significantly highest performance in vegetative development. That reflect the highest leaves length (71 cm), leaf base length (15.33 cm), length of third internode from top (9.6 cm), number of rachilas (17.33). Thus, Honey accumulates the highest dry matter which define enrich with minerals and carbohydrates and protein concluding vitamin particles. That's why the highest fresh weight (730.51 g) observed by Honey and had highest dry weight (158.07 g).

In case of fresh (26.24 g) and dry (5.98 g) weight of roots Honey also showed significant difference with all others plant growth regulators. Though Rooton hormone showed statistically similar result in roots number (18.67) and branch number (6), but in case of fresh (600.01 g) and dry (121.80 g) weight of shoot it showed 17.9% and 22.9% less results than Honey respectively.

CHAPTER V

SUMMARY AND CONCLUSION

SUMMARY

The experiment was conducted at the Agroforestry Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh to determine the response of moringa in response to plant growth regulators. The experiment consisted of five treatments, T_1= Honey, T_2= Rooton hormone, T_3= Auxin, T_4= Cutting hormone and T_5= Water (control). The Experiment was conducted in CRD design with eight replications within six months. Data on growth and yield contributing characters were recorded and significant variation was observed.

In case of moringa at 15, 30, 45 and 60 DAT the highest number of buds were found in Honey (3, 4.33, 4.33 and 6.67) and the lowest number of buds were found in Cutting hormone (0.67, 1.33, 1.33 and 1.67). The highest number of branches per plant found in honey (6.67) and lowest number of branches found in Cutting hormone (1.67). For plant growth regulator highest number of leaves per plant found for Honey (53.67) and lowest number of leaves per plant found in Cutting hormone (13.67).

Maximum leaves length per plant found for Honey (71 cm) and minimum leaves length per plant found in Cutting hormone (44.67 cm). Maximum leaves base length per leaf found in Honey (15.33 cm) and minimum leaves base length per leaf found in Cutting hormone (13.33 cm). Highest third internode length of leaves from top found in Honey (9.6 cm) and lowest length found in cutting hormone in (7.57 cm). Maximum number of rachilas per leaves found in Honey (17.33) and minimum number found in cutting hormone (14).

Highest number of leaflets per leaves found in Cutting hormone (398.67) and lowest number of leaflets number found in Honey (331.67). Maximum number of roots per plant found in Honey (20.33) and minimum number of roots per plant found in

Cutting hormone (9.33). Highest root length per plant found in honey (18 cm) and lowest root length per plant found in Cutting hormone (9.33 cm).

Highest fresh weight of roots per plant found in Honey (26.24 g) and lowest fresh weight of roots per plant found in Cutting hormone (9.01 g). Highest fresh weight of shoot per plant found in Honey (730.51 g) and lowest fresh weight of shoot per plant found in Cutting hormone (149.11 g). Again, highest dry weight of roots found in Honey (5.98 g) and lowest dry weight of roots found in Cutting hormone (2.10 g). Highest dry weight of shoot found in Honey (158.07 g) and lowest weight of shoot per plant found in Cutting hormone (33.76 g).

CONCLUSION

Considering the findings of the experiment, it may be concluded that among applied plant growth regulators some of the hormones showed excellent performance in different stage of growth and development of Moringa cuttings. Honey appeared as the best treatment in this experiment. Honey showed highest result in branching (6.67), number of leaves (53.67) and rooting (20.33) per plant. Honey also showed superior result in fresh and dry weight of root (5.98 g) and shoot (158.07 g). Rooton hormone closely followed honey's result but the lowest result found in almost all parameter with cutting hormone. Thus, the moringa cuttings were observed to propagated in terms of root and vegetative parameters with honey than other hormones in Moringa cuttings propagation.

RECOMMENDATIONS

Further repeated study should be conducted using different alternative hormones on the vegetative propagation of Moringa cuttings before recommending for nursery industry.

Different alternative phytohormones could also be assessed on typical agroforestry tree species propagation to produce true-to type quality saplings.

CHAPTER VI

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CHAPTER VII

APPENDICES

Appendix I. Characteristics of the soil of experimental field analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the soil of experimental field

Morphological features	Characteristics
Location	Aminbazar, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% Clay	30
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: SRDI, 2012

Appendix II. Analyzed data on effect of different plant hormones on bud formation of moringa at 15 DAT.

```
Response: Dat15
          Df  Sum Sq Mean Sq F value   Pr(>F)
Treatment  4 11.3333 2.83333  10.625 0.001266 **
Residuals 10  2.6667 0.26667
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> lsd=LSD.test(model,"Treatment")
$`statistics`
   MSerror Df Mean       CV  t.value       LSD
  0.2666667 10    2 25.81989 2.228139 0.9394658

$groups
      Dat15 groups
2 3.0000000      a
1 2.6666667      a
3 2.3333333      a
5 1.3333333      b
4 0.6666667      b
```

Appendix III. Analyzed data on effect of different plant hormones on bud formation of moringa at 30 DAT.

```
Response: D30
          Df  Sum Sq Mean Sq F value   Pr(>F)
Treatment  4 20.2667  5.0667  10.857 0.001163 **
Residuals 10  4.6667  0.4667
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> lsd=LSD.test(model,"Treatment")
$`statistics`
   MSerror Df     Mean       CV  t.value      LSD
  0.4666667 10 3.066667 22.27598 2.228139 1.242796

$groups
       D30 groups
1 4.333333      a
2 4.333333      a
3 3.000000      b
5 2.333333     bc
4 1.333333      c
```

Appendix IV. Analyzed data on effect of different plant hormones on bud formation of moringa at 45 DAT.

```
Response: D30
          Df  Sum Sq Mean Sq F value   Pr(>F)
Treatment  4 20.2667  5.0667  10.857 0.001163 **
Residuals 10  4.6667  0.4667
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
> lsd=LSD.test(model,"Treatment")
$`statistics`
   MSerror Df     Mean       CV  t.value      LSD
  0.4666667 10 3.066667 22.27598 2.228139 1.242796

$groups
       D30 groups
1 4.333333      a
2 4.333333      a
3 3.000000      b
5 2.333333     bc
4 1.333333      c
```

Appendix V. Analyzed data on effect of different plant hormones on bud formation of moringa at 60 DAT.

```
Response: D60
          Df Sum Sq Mean Sq F value    Pr(>F)
Treatment  4   51.6    12.9    64.5 4.205e-07 ***
Residuals 10    2.0     0.2
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
> lsd=LSD.test(model,"Treatment")
$`statistics`
  MSerror Df Mean       CV  t.value       LSD
      0.2 10  4.4 10.16395 2.228139 0.8136013

$groups
       D60 groups
1 6.666667      a
2 6.000000      a
3 4.666667      b
5 3.000000      c
4 1.666667      d
```

Appendix VI. Analyzed data on effect of different plant hormones on number of branches of moringa per plant.

```
Response: NB
          Df Sum Sq Mean Sq F value    Pr(>F)
Treatment  4   51.6    12.9    64.5 4.205e-07 ***
Residuals 10    2.0     0.2
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> lsd=LSD.test(model,"Treatment")
$`statistics`
  MSerror Df Mean       CV  t.value       LSD
      0.2 10  4.4 10.16395 2.228139 0.8136013

$groups
        NB groups
1 6.666667      a
2 6.000000      a
3 4.666667      b
5 3.000000      c
4 1.666667      d
```

Appendix VII. Analyzed data on effect of different plant hormones on number of leaves of moringa per plant.

```
Response: NL
          Df Sum Sq Mean Sq F value    Pr(>F)
Treatment  4 3358.4   839.6  82.314 1.302e-07 ***
Residuals 10  102.0    10.2
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> lsd=LSD.test(model,"Treatment")
$`statistics`
  MSerror Df Mean       CV  t.value      LSD
     10.2 10 35.8 8.921072 2.228139 5.810275

$groups
        NL groups
1 53.66667      a
2 49.66667      a
3 37.00000      b
5 25.00000      c
4 13.66667      d
```

Appendix VIII. Analyzed data on effect of different plant hormones on length of leaves of moringa per plant.

```
Response: LL
          Df  Sum Sq Mean Sq F value    Pr(>F)
Treatment  4 1322.27  330.57  12.213 0.0007295 ***
Residuals 10  270.67   27.07
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
> lsd=LSD.test(model,"Treatment")
$`statistics`
   MSerror Df     Mean       CV  t.value      LSD
  27.06667 10 53.06667 9.803826 2.228139 9.464856

$groups
        LL groups
1 71.00000      a
2 53.33333      b
3 48.66667      b
5 47.66667      b
4 44.66667      b
```

Appendix IX. Analyzed data on effect of different plant hormones on leaves base length of moringa per plant.

```
Response: LBL
          Df Sum Sq Mean Sq F value    Pr(>F)
Treatment  4 57.733 14.4333  16.654 0.0002026 ***
Residuals 10  8.667  0.8667
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
> lsd=LSD.test(model,"Treatment")
$`statistics`
    MSerror Df Mean       CV  t.value      LSD
  0.8666667 10 12.2 7.630732 2.228139 1.693646
$groups
       LBL groups
1 15.33333      a
2 13.66667      a
5 11.00000      b
3 10.66667      b
4 10.33333      b
```

Appendix X. Analyzed data on effect of different plant hormones on third internode length of leaves from top.

```
Response: NL
          Df Sum Sq Mean Sq F value    Pr(>F)
Treatment  4 9.7973  2.4493  39.505 4.258e-06 ***
Residuals 10 0.6200  0.0620
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> lsd=LSD.test(model,"Treatment")
$`statistics`
  MSerror Df     Mean     CV  t.value      LSD
    0.062 10 8.513333 2.9248 2.228139 0.452994
$groups
        NL groups
1 9.600000      a
2 9.266667      a
3 8.400000      b
5 7.733333      c
4 7.566667      c
```

Appendix XI. Analyzed data on effect of different plant hormones on rachilas number per leaf.

```
Response: NRch
          Df Sum Sq Mean Sq F value   Pr(>F)
Treatment  4   21.6     5.4       9 0.002385 **
Residuals 10    6.0     0.6
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> lsd=LSD.test(model,"Treatment")
$`statistics`
  MSerror Df Mean       CV  t.value      LSD
      0.6 10 15.4 5.029849 2.228139 1.409199

$groups
      NRch groups
1 17.33333      a
2 16.00000     ab
3 15.33333     bc
5 14.33333      c
4 14.00000      c
```

Appendix XII. Analyzed data on effect of different plant hormones on leaflets number per leaf.

```
Response: LfltN
          Df Sum Sq Mean Sq F value  Pr(>F)
Treatment  4 8787.1 2196.77  5.8852 0.01062 *
Residuals 10 3732.7  373.27
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> lsd=LSD.test(model,"Treatment")
$`statistics`
   MSerror Df     Mean       CV  t.value      LSD
  373.2667 10 363.4667 5.315511 2.228139 35.14845

$groups
     LfltN groups
4 398.6667      a
5 381.3333     ab
3 361.0000     bc
2 344.6667      c
1 331.6667      c
```

Appendix XIII. Analyzed data on effect of different plant hormones on root number per plant.

```
Response: NRt
          Df  Sum Sq Mean Sq F value   Pr(>F)
Treatment  4 233.733  58.433  15.936 0.000244 ***
Residuals 10  36.667   3.667
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> lsd=LSD.test(model,"Treatment")
$`statistics`
   MSerror Df Mean       CV  t.value      LSD
  3.666667 10 15.2 12.59773 2.228139 3.483633
$groups
        NRt groups
1 20.333333      a
2 18.666667      a
3 14.666667      b
5 13.000000      b
4  9.333333      c
```

Appendix XIV. Analyzed data on effect of different plant hormones on length of roots per plant.

```
Response: RtL
          Df  Sum Sq Mean Sq F value    Pr(>F)
Treatment  4 138.667  34.667  74.286 2.136e-07 ***
Residuals 10   4.667   0.467
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> lsd=LSD.test(model,"Treatment")
$`statistics`
   MSerror Df     Mean       CV  t.value      LSD
  0.4666667 10 13.33333 5.123475 2.228139 1.242796

$groups
        RtL groups
1 18.000000      a
2 15.333333      b
3 12.666667      c
5 11.333333      d
4  9.333333      e
```

Appendix XV. Analyzed data on effect of different plant hormones on fresh weight of roots per plant.

```
Response: FWR
          Df Sum Sq Mean Sq F value   Pr(>F)
Treatment  4 573.05 143.262  83.433 1.22e-07 ***
Residuals 10  17.17   1.717
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> lsd=LSD.test(model,"Treatment")
$`statistics`
   MSerror Df     Mean       CV  t.value      LSD
  1.717087 10 16.45733 7.962265 2.228139 2.383926

$groups
       FWR groups
1 26.24000      a
2 20.61000      b
3 14.09667      c
5 12.33000      c
4  9.01000      d
```

Appendix XVI. Analyzed data on effect of different plant hormones on fresh weight of shoot per plant.

```
Response: FWS
          Df Sum Sq Mean Sq F value    Pr(>F)
Treatment  4 697254  174314  198.66 1.761e-09 ***
Residuals 10   8775     877
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> lsd=LSD.test(model,"Treatment")
$`statistics`
   MSerror Df     Mean       CV  t.value      LSD
  877.4552 10 439.2833 6.743226 2.228139 53.89011

$groups
       FWS groups
1 730.5067      a
2 600.0100      b
3 469.0467      c
5 247.7433      d
4 149.1100      e
```

Appendix XVII. Analyzed data on effect of different plant hormones on dry weight of roots per plant.

```
Response: DWR
          Df  Sum Sq Mean Sq F value    Pr(>F)
Treatment  4 29.2002  7.3000  84.733 1.132e-07 ***
Residuals 10  0.8615  0.0862
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> lsd=LSD.test(model,"Treatment")
$`statistics`
     MSerror Df     Mean       CV  t.value       LSD
  0.08615333 10 3.746667 7.834134 2.228139 0.5339894

$groups
       DWR groups
1 5.980000      a
2 4.656667      b
3 3.200000      c
5 2.800000      c
4 2.096667      d
```

Appendix XVIII. Analyzed data on effect of different plant hormones on dry weight of shoot per plant.

```
Response: DWS
          Df  Sum Sq Mean Sq F value   Pr(>F)
Treatment  4 30403.8  7600.9  110.88 3.07e-08 ***
Residuals 10   685.5    68.6
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
> lsd=LSD.test(model,"Treatment")
$`statistics`
   MSerror Df     Mean       CV  t.value      LSD
  68.55265 10 92.79267 8.922745 2.228139 15.06291


$groups
        DWS groups
1 158.06667      a
2 121.80333      b
3  96.68333      c
5  53.65333      d
4  33.75667      e
```

PLATES

Plate 1. Soil Preparation

Plate 2. Poly Bag Preparation & Cuttings Transplanting

Plate 3. Experimental Site

Plate 4. Bud Formation

Plate 5. Data Collection

Plate 6. Taking Fresh Weight