

**AKENTEN APPIAH- MENKA UNIVERSITY OF SKILLS
TRAINING AND ENTREPRENEURIAL DEVELOPMENT
FACULTY OF AGRICULTURE EDUCATION
MAMPONG – ASHANTI**

**GROWTH, YIELD AND FRUIT QUALITY OF PLANTAIN
(*Musa paradisiaca*) AS INFLUENCED BY DIFFERENT
SOURCES OF NATURAL ROOTING HORMONES AND
DIPPING TIME**

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MASTER OF PHILOSOPHY IN CROP SCIENCE
(AGRONOMY)**

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**AKENTEN APPIAH- MENKA UNIVERSITY OF SKILLS TRAINING AND
ENTREPRENEURIAL DEVELOPMENT (AAMUSTED)
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**A THESIS IN THE DEPARTMENT OF CROP AND SOIL SCIENCES
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UNIVERSITY OF SKILLS TRAINING AND ENTREPRENEURIAL
DEVELOPMENT**

NOVEMBER, 2025

DECLARATION

STUDENT’S DECLARATION

I hereby declare that except for references to the work of other researchers which have been duly cited, this work is a result of my original research and that this thesis has neither in whole nor in part been presented elsewhere for the award of another degree.

CANDIDATE’S NAME: EMMANUEL ADJEI BAAFI

DATE

SIGNATURE.....

SUPERVISOR’S DECLARATION

I hereby declare that the preparation and presentation of this thesis were supervised following the guidelines for supervision of thesis as laid down by Akenten Appiah- Menka University of Skills Training and Entrepreneurial Development (AAMUSTED).

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DEDICATION

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TABLE OF CONTENTS

DECLARATION	iii
ACKNOWLEDGEMENT	iv
DEDICATION	v
TABLE OF CONTENTS	vi
LIST OF TABLES	ix
LIST OF FIGURES	x
LIST OF ABBREVIATIONS	xi
ABSTRACT	xii
CHAPTER ONE: INTRODUCTION	1
1.1 Background of the Study	1
1.2 Problem Statement and Justification.....	2
1.3 Research Objectives.....	4
<i>1.3.1 Main Objective</i>	4
<i>1.3.2 Specific Objectives</i>	4
CHAPTER TWO: LITERATURE REVIEW	5
2.1 Origin and Distribution	5
2.2 Botany	7
2.3 Nutritional value and uses.....	9
2.4 Varieties.....	10
2.5 Environmental Growth Requirements	11
2.6 Production Estimate	12
2.7 Crop Propagation	13
2.8 Agronomic Practices	16
2.9 Harvesting and Fruit Handling.....	19

2.10 Effect of Different Rooting Hormones on Growth and Yield of Plantain	21
2.11 Effect of Rooting hormones and Dipping Time on Plantain Growth and Yield	24
2.12 Effect of rooting hormones and dipping times on plantain fruit quality.....	26
CHAPTER THREE: MATERIALS AND METHODS	29
3.1 Experimental Location and Description	29
3.2 Experimental Design and Treatments	30
3.2.1 <i>Experimental design</i>	30
3.2.2 <i>Treatments</i>	30
3.3 Source of Plantain Plantlets (Minisetts using the Split corm technique) and Preparation	31
3.4 Rooting Hormones Preparation.....	32
3.4.1 <i>Fresh coconut water</i>	32
3.4.2 <i>Honey</i>	32
3.4.3 <i>Water</i>	33
3.5 Pre -Planting Activities	33
3.5.1 <i>Land Preparation</i>	33
3.5.2 <i>Fencing of Experimental Field</i>	33
3.6 Nursery Preparations and Transplanting of Plantain Plantlets.....	34
3.7 Agronomic Practices	35
3.8 Data Collected.....	35
3.9 Data Analysis	38
CHAPTER FOUR: RESULTS	39
4.1 Weather conditions at the Experimental sites	39
4.2 Phenology	39
4.2.1 <i>Days to 50 % fruiting and maturity</i>	39

4.3 Vegetative Growth.....	40
4.3.1 <i>Plant height of suckers around each mother plant</i>	40
4.3.2 <i>Height of mother plant</i>	42
4.3.3 <i>Number of leaves per plant</i>	44
4.3.4 <i>Stem girth</i>	46
4.3.5 <i>Number of suckers per parent plant</i>	48
4.4 Yield and Yield Components.....	51
4.4.1 <i>Number of suckers per plot and bunch weight per plot at harvest</i>	51
4.4.2 <i>The number of fingers per bunch at harvest and bunch stalk diameter</i>	52
4.4.3 <i>Bunch length at harvest and yield</i>	53
4.5 Correlation Matrix Analysis.....	54
CHAPTER FIVE: DISCUSSION.....	59
5.1 Phenology of Plantain as Affected by Coconut Water, Honey, Water and Dipping Time	59
5.2 Vegetative Growth of Plantain as Affected by Coconut Water, Honey, Water and Dipping Time.....	60
5.3 Effect of rooting hormones (Coconut water, Honey and Water) and dipping time on Plantain yield and yield components.....	65
CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS.....	70
6.1 Conclusion	70
6.2 Recommendations.....	70
REFERENCES.....	72
APPENDICE	87

LIST OF TABLES

Table 3.1: Treatment combinations	30
Table 4.1 Number of days to 50% fruiting and days to maturity as influenced by different rooting hormones and dipping time	40
Table 4.2 Number of suckers and bunch weight at harvest as influenced by rooting hormones and dipping time	52
Table 4.3 Number of fingers per bunch at harvest and bunch stalk diameter as influenced by rooting hormones and dipping time	53
Table 4.4 Bunch length at harvest and yield as influenced by rooting hormones and dipping time.....	54
Table 4.5 Correlation matrix among growth, yield and yield parameters of plantain as influenced by rooting hormones and dipping time.....	58

LIST OF FIGURES

Figure 4.1a: Height of suckers as influence by rooting hormones and dipping time.....	41
Figure 4.1b: Height of suckers as influenced by the interactions of the rooting hormones and dipping time	42
Figure 4.2a: Plant height of mother plant as influenced by rooting hormones and dipping time	43
Figure 4.2b: Plant height of mother plant as influenced by the interactions of the rooting hormones and dipping time	44
Figure 4.3a: Number of leaves per plant as influenced by rooting hormones and dipping time	45
Figure 4.3b: Number of leaves per plant as influenced by interactions of rooting hormones and dipping time.....	46
Figure 4.4a Stem girth as influenced by rooting hormones and dipping time	47
Figure 4.4b Stem girth as influenced by the interaction of rooting hormones and dipping time	48
Figure 4.5a: Number of suckers per plant as influenced by rooting hormones and dipping time.....	50
Figure 4.5b: Number of suckers per plant as influenced by the interaction of rooting hormones and dipping time	50

LIST OF ABBREVIATIONS

CMA	Correlation Matrix Analysis
CSIR	Council for Scientific and Industrial Research
CRI	Crops Research Institute
CV	Coefficient of Variation
DPPA	Dichlorophene Propanoic Acid
FAO	Food and Agriculture Organization
GenStat	General Statistics
Genome A	Acuminate
Genome B	Balbisiana
HD	Hours of Dipping
HSD	Honestly Significant Difference
IAA	Indole Acetic Acid
IBA	Indole Butyric Acid
IITA	International Institute of Tropical Agriculture
LSD	Least Significant Difference
MNL	Mean Number of Leaves
NAA	Naphthalene Acetic Acid
NAAM	Naphthalene Acetamide
OH,	Organic Hormone
PGPR	Plant growth promotor rhizobacteria
QD	Quick Dip
RCBD	Randomized Complete Block Design

ABSTRACT

An experiment was conducted at Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development Multipurpose Crop Nursery to evaluate the efficacy of coconut water, honey as natural hormones and water as the control on growth, yield and fruit quality of plantain from March to November 2023. The experimental design used was a 3 x 3 factorial arranged in a Randomized Complete Block Design (RCBD) with three replications. The treatments were three dipping time namely (quick dip, 2-hour dip, and 4-hour dip) and three rooting hormones (coconut water, honey and water as the control). The results showed that treating plantain corms with coconut water and honey (a natural rooting hormone solution) and with 4-hour dip enhanced some vegetative growth parameters and yield and yield components of plantain. It was established from the finding that the coconut water plus 4-hour dip gave the least number of days to fruit maturity, greatest number of leaves per plant at 9 months after planting, widest bunch stalk diameter, heaviest bunch weight at harvest and the highest yield compared to the other treatments. For a higher plantain yield, it is recommended that farmers should use coconut water as rooting hormone to treat plantain corms and also dip them for 4-hour before planting to optimize plantain productivity.

CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

Plantain (*Musa paradisiaca* L.) is a major starchy staple in Ghana. Plantains play a significant role in the production of food in Ghana (Ukwuaba *et al.*, 2022a). Even though the terms "banana" and "plantain" are frequently used interchangeably, true plantains produce relatively starchy fruits and require processing before eating, such as boiling, drying, and frying. In contrast, banana cultivars produce fruits that are relatively sweet and can be eaten raw when ripe. Plantain (*Musa paradisiaca* L.) and Banana (*Musa sapientum* L.) are important in all tropical regions. In Africa, the crop provides more than 25% of food energy requirements for around 70 million people. Plantains are source of carbohydrate, protein, vitamins and minerals (Dépigny *et al.*, 2019).

Unripe plantains contain about 80% carbohydrate as a major component of food nutrients with significantly high levels of Nitrogen, Phosphorus, Potassium, Magnesium, Calcium, and vitamins in fully ripe plantain pulp, but low levels of Iron (Fe), Copper (Cu), Zinc (Zn), Sodium (Na) (Marimo *et al.*, 2020). The flavonoid leucocyanidin has been identified as the active ingredient in plantain for its anti-ulcerogenic properties. Traditional medicine has also employed plantain sap to treat several ailments, including leprosy, fever, digestive issues, and even insect stings (Bogale, 2018). The crop also serves as shade plant for other important tree species such as coffee and cocoa and therefore is an integral part of the Agroforestry farming system (Ukwuaba *et al.*, 2022b). The main purpose of growing the crop next to cocoa is to provide shade for the seedlings (Kikulwe and Asindu 2020). The pseudostem is sometimes left on the field after the crop has been harvested to serve as organic matter in addition to being used for fibre. In some fishing settlements in West Africa, the fibre obtained from the pseudostem of plantain is utilized to produce fishing

lines. The pseudostem of the plantain plant can yield sap that can be utilized for mordanting purposes. The dye industry, particularly the "Adinkra" sector in Ghana, has enormous potential, as demonstrated by the sap from plantain trees and stem bark (Diarsa and Gupte 2020).

Plantain and banana can be propagated with natural and artificial plant hormones. Natural plant hormones have been exploited to enhance the propagation of several important horticultural crops, including plantain and banana. Smallholder farmers in sub-Saharan Africa may use coconut water as an available source of plant hormone to enhance the production of young plantain plantlets. This will allow the regular establishment of plantain fields when the replacement of old and unproductive fields becomes necessary (Abdel-Rahman *et al.*, 2020).

1.2 Problem Statement and Justification

Despite the significant benefits of plantain to farmers and Ghana at large, its production is severely hampered by factors including increasing population growth, problems with land tenure, fewer periods when land is left to fallow, declining soil fertility, complex and increased pest and disease pressures, drought, and wind attacks. Again, synthetic hormones are scarce in our major Research Institutions and at the chemical market with incredibly high prices, which local farmers cannot afford to buy even if they are available. In addition, most farmers lack the expertise and the required apparatus to carry out rigorous calculations with the use of synthetic hormones leading to poor establishment and subsequently yield.

By feeding more people per unit of production than other staple crops, investment in plantain improvement technologies has the potential to greatly improve food security

(Uzakah, 2020). Various methods have been developed to address the lack of adequate certified planting material of plantain in large numbers and this includes the split-corm, tissue culture (in vitro), and decapitation techniques as well as other micro and macro propagation multiplication methods which have been reported to significantly enhance the growth and yield of plantain. Plantain plantlets are obtained from various techniques such as tissue culture, bud manipulation, and the split corm multiplication technique of raising quality and healthy plantlets needed to meet the commercial demand of suckers. According to Opata *et al.* (2021c), split corm technique is the appropriate and inexpensive method of rapid field multiplication of plantains.

Plant hormones are often needed to boost the survival and growth of axillary buds which are characterized by the use of mainly synthetic plant hormones. The use of plant hormones is proven in many research works to enhance the vigour with the use of an appropriate concentration of synthetic auxins and other related hormones at a particular dipping rate to induce root growth of plantain plantlets in sucker production. Maiden plantain sucker manipulation to realize healthy suckers is proven and established in many research institutions to avoid pest and disease infestation, producing well-developed root systems and improved sprouting rate. This practice becomes easier with the use of natural hormones which are readily available and accessible to the local farmers and environmentally friendly with high performance compared to other studies that employed the use of artificial hormones.

Tenkouano and Hanser (2019) reported that, due to the sophistication nature of the required equipment and the lack of technical know-how on the side of the local farmers, to embark on tissue culture multiplication at the laboratory they were discouraged and corm

multiplication. However, little research has been conducted on the use of coconut water and honey on the growth and yield of plantain. Hence the need to evaluate the effect of readily available materials such as coconut water and honey on the growth, yield and fruit quality of plantain.

1.3 Research Objectives

1.3.1 Main Objective

The main objective of the study was to determine the growth, yield and fruit quality of plantain as affected by different rooting hormones and dipping time.

1.3.2 Specific Objectives

Specifically, the study objectives were to:

1. Determine the effect of different rooting hormones (water, coconut water and honey) on growth and yield of plantain.
2. Evaluate the effectiveness of different dipping time (quick dip, 2-hours, and 4-hours) on yield of plantain.
3. Assess the interactive effect of different dipping time and rooting hormones on yield and fruit quality of plantain.

CHAPTER TWO: LITERATURE REVIEW

2.1 Origin and Distribution

Plantain which originated from South-East Asia is a staple food in African countries and Central and South America. The history has been very difficult to trace in the archaeobotanical record. The development of this exceptional diversity in Africa can only be explained by a century-long accumulation of somatic mutants from presumably a few basic cultivars introduced from Asia. It has even been suggested that the arrival of plantains in west-central Africa caused an agricultural and demographic revolution which drove the expansion of speakers of Bantu-languages. The base of current rainforest agriculture is formed by *Musa* species of the AAB group (plantain) (Njoku, 2021).

Plantain is a subsistence crop, the traditional farmer tends to maintain all cultivars, whatever their productivity. However, the bunches of a number of cultivars have a special post-harvest value, such as resistance to damage during transportation and various particular consumer-attractive aspects of bunch and fruits in the local markets. The wide diversity of plantain cultivars in west and central Africa has been described and classified using morphological traits (Twesigye *et al.*, 2018).

The plant has corms/bulbs, a central bud that is responsible for leaf production, and lateral buds which eventually grows to produce suckers. Plantains are of the genus *Musa* with family Musaceae and are believed to have been obtained from *Musa acuminata* and *Musa balbisiana*. Plantains (*Musa* spp.), a tall herbaceous crop, are grown in the humid, subtropical rain forests of Africa. Its origin in sub-Saharan Africa is a topic of intense controversy, but most experts agree that it originated in South East Asia (Chabi *et al.*, 2018). Nigeria is one of the largest plantain producing countries in the world. Despite its

prominence, Nigeria does not feature among plantain exporting nations. It produces more for local consumption than export (Fainou *et al.*, 2018).

Although a staple food, plantains are also utilized in the food industry to make chips, flakes, cakes, and flours. This leads to significant employment opportunities for the general public, either directly or indirectly, and always increases the income of smallholder farmers. In households, plantains can be consumed when cooked and mashed with gari or to make fufu, fried to make a dodo, boiled and eaten with beans, roasted and eaten with groundnuts or palm oil, or dried and mixed into flour to be used as an ‘alibi’ (Olah, 2019). Youth involvement in plantain production is essential for the advancement and welfare of young people in rural areas. Worldwide, plantains are a key source of food. In order to close the gap between the supply and demand of basic energy staple foods, plantains are essential. Plantain cultivation in Nigeria is growing in importance as a means of generating revenue for both small and large-scale farmers, particularly for those who grow it in their backyard gardens (Koch *et al.*, 2022).

With an annual production of over 3.2 million tons, Nigeria is the second-largest producer of plantains in West Africa, after Ghana, and ranks fifth globally after Ghana, the Democratic Republic of the Congo, Cameroun, and Uganda (HONFO *et al.*, 2020) Plantain (*Musa* spp. AAB) is an important starchy staple crop and a key component of the farming systems in the humid lowland ecologies of West and Central Africa. This region harbors the world’s greatest variability of plantains since they have been cultivated for about 2500 years, and it is, therefore, considered a secondary center of plantain diversification (Chabi *et al.*, 2018).

Plantains is one of the important staple food crops consumed in the tropics behind rice, wheat and maize and are obtainable in about 120-130 tropical countries in the world. It is

an essential food crop in sub-Saharan Africa that serves as source of nutrient and household income for many people around the world. The aggregated world production is put at over 76 million metric tons, out of which over 12 million metric tons are harvested yearly in Africa. Africa with an estimated production of about 2.7 million metric tons, majority of which are produced and harvested from the southern part of the Africa (Kumar *et al.*, 2020). In spite of large tons of plantains harvested yearly in Africa, over 50% of plantains harvested are lost due to unavailability of appropriate storage facilities to prevent postharvest losses. These large productions and post-harvest losses necessitate the need to develop new and suitable technologies for processing and preservation of plantain flour from time to come (Okafor, 2019).

2.2 Botany

Although they are frequently called rhizomes, plantains are both herbaceous perennials with short subterranean stems known as corms. The corm, which is the actual stem, is made up of a central bud, also known as an apical meristem or central growing point, which is where the bunch forms and where the leaves and flowers are initiated (Mohammed, 2021). The pseudostem can grow to a height of 2 to 8 m based on the variety and conditions necessary for growth and development (Twesigye *et al.*, 2018).

Despite having no woody substance, the massive, widely opened leaves can be supported by the stem. Because of its capacity to store vast amounts of water, plantains can withstand prolonged dry spells but during these times, their pace of growth slows down (J. Opata *et al.*, 2020).

Plantain is an herbaceous perennial with short underground stems which are corms although they are sometimes referred to as Rhizomes. The corm is the real stem and it

consists of a central bud (central growing point or apical meristem) from which the leaves and the flowers are initiated and from which the bunch is formed (Mohammed, 2021).

It is a vertical underground stem surrounded by several buds covered in a protective cortex of the corm. Suckers emerge from the buds on the outer surface of the cortex. The corm also gives rise to lateral buds (meristems) which become the eyes and some of which eventually develop into suckers. The number of eyes that develop into suckers varies considerably according to cultivars as well as the stage of growth reached by the parent plant (Bhende *et al.*, 2018).

The true stem of plantain plant is partly or wholly under-ground and is known technically as tuberous rhizome. The rhizome remained below the surface of the soil. Suckers are swollen buds initially developed from lateral meristems at the leaf bases on the corm. The first plantain that grows from planted suckers is called the plant crop or mother plant.

A sucker which has been set to produce fruit is called a follower or daughter plant and later a ratoon (Mekoa and Hauser 2019).

Generally, there are four types of suckers described as follows; peepers are small suckers, which appear just above the ground. The second type is a sword sucker which is large with lanceolate leaves. The third type is the maiden sucker which is a large, none fruiting ratoon sucker, taller, more than 100 cm and has large leaves. The fourth is a water sucker; it is a small sucker with large leaves and a small corm due to shallow origin or poor underground links with the mother plant. However, suckers continue to emerge from a single mat year after year, making plantain perennial crop (Mengesha *et al.*, 2018).

Corm manipulation is a faster technique of inducing plantlets (suckers) production from plantain corms removed from the field plants. One approach involves destroying the apical meristem of a relatively large corm and planting it whole in moist nursery substrate under warm and humid conditions in a humidity chamber. Lateral buds are thus stimulated to

sprout, and the shoots produced are removed and hardened in the nursery to obtain small plants. Cutting off these shoots reduces apical dominance further and stimulates more sprouting. Several studies have demonstrated that large numbers of clean and healthy plantlets can be produced by macro propagation from a corm (Dzomeku, 2020).

2.3 Nutritional value and uses

For millions of individuals, plantain fruits are an excellent source of vitamins and minerals for their diets. Plantains are an excellent source of energy because they contain 32% of their weight in carbohydrates. According to Opata *et al.* (2021), Plantain contains notable amounts of minerals, dietary fiber, vitamins A, B6, and C. It is suitable for hypertensive people and devoid of cholesterol. It has less salt significant amounts of iron, potassium, calcium, vitamin A, thiamin, riboflavin, niacin, ascorbic acid, dietary fiber, and resistant starch are present in it, all of which contribute to lowering blood sugar levels (Oko *et al.*, 2019).

The crushed leaves stop wounds from bleeding. Plantain sap has also been used in traditional medicine to treat a variety of conditions, such as fever, digestive problems, and insect stings, while fried plantain bracts have anti-diabetic properties. The need for a hygienic, effective drying method is essential during plantain flour preparation. The end use of plantain flour in food depends on the attractiveness of its colour. Enzymatic browning reaction is one of the problems encountered during plantain processing and this reaction often affects the colour of the flour produced from plantain. The browning reactions usually occur during processing as a result of the activity of polyphenol oxidase (tyrosinase). A good flour for baking is plantain powder. It is therefore essential to pretreat plantain slices during processing to arrest the browning, which if not arrested may affect the colour of the final product (Oladimeji and Fadimu 2018a).

At the moment, Ghana's agro-industry is assuming a pivotal strategic role by turning vast amounts of plantains into flour and producing plantain chips from the green fruits, both of which are intended for export and domestic consumption (J. M. Opata et al., 2021)(Udomkun *et al.*, 2021).

There are numerous uses for plantain leaves outside of food in different parts of the world. After the crop is harvested, the pseudostem is occasionally left on the field to act as organic matter in addition to being used as fiber. The fiber from the pseudostem of plantains is used to make fishing lines in several fishing villages in West Africa (Kikulwe and 2020).

Plantain processing helps to minimize waste, particularly at the busiest time for production. In addition, it produces revenue, jobs, and commercialization prior to being introduced to the market (Pessarakli, 2019). With the exception of processing, plantains have a lower shelf life since they decay more quickly. Processing has sustained the interest of farmers and other related stakeholders in the plantain subsector and to help address pressing concerns of glut and postharvest loss, particularly during the peak time. Furthermore, because processed goods have additional value, their prices are greater (Oladimeji and Fadimu 2018b).

2.4 Varieties

Plantain may be classified according to their bunch morphology and the taste of the pulp formed. Neutral or intermediate flowers occur in the middle of the inflorescence and do not form fruits. At the end of the fruiting stalk of plantain is a large purple knob called the male bud which consists of bracts covering a group of male flowers. The three common groups grown in Ghana include, 'Apem', 'Apantu', and intermediate (*Muller et al.*, 2021). 'Apem' and 'Apantu' correspond respectively to the Giant French plantain and false plantain

cultivars. A major local cultivar within the intermediate group is the True horn. It is not prolific and therefore not grown widely by farmers (locally referred to as ‘Asamienu’ and ‘Aowin’). This variety is robust, 70 – 75cm tall (Adheka et al., 2018b).

2.5 Environmental Growth Requirements

Climate change due to increase greenhouse gases and atmospheric concentrations are expected to have an important impact on the environment such as agriculture, forestry and energy consumptions. For agriculture, change in climate have significant impacts on crop growth and yield, since these are largely determined by the weather conditions during the growing season (Waadt *et al.*, 2022). Plantain needs a lot of water. It should get around 200 mm per month or effective rainfall between 1650-1700 mm throughout its life cycle. However, considering the increasing pressure of the climate there is the need for irrigation or water requirements to improve plantain growth and yield (Okafor, 2019). Plantain production requires the wet season and the dry season mostly under rainfed cultivation.

The optimal temperature for growing plantain is 28 °C, from 28°C to 20°C, growth will gradually slow down and will become negligible around 16 °C to 18°C. Plantain is a long day plant however flowering behaviour can be altered by ambient temperature requirements for plantain inflorescence (Okafor, 2019). Due to their extreme sensitivity to wind, plantains may physically suffer harm such as tumbling over or breaking stems. In the case of soil characteristics nutrient requirements in plantain-based farming systems are addressed by the application of poultry and cattle manure. However, goat, and swine manure are produced in negligible quantities to support plantain production (Ekpo and Ekpo 2019).

Kumar *et al.* (2020) identified a set of variables such as microbial biomass and water content, pH and electric conductivity as the related soil qualities that improves plantain production. Sometimes these studies tried to identify the relationship between soil properties modified by specific agronomic practices, with yield and plant physiological responses, as in the case of which explored the effect of organic amendments in plantain on soil quality and root development (Olivares *et al.*, 2020). Deep, nutrient-rich, well-drained soil is ideal for plantain growth.

2.6 Production Estimate

Plantain and banana constitute perhaps the most complex food group among the roots, tubers and bananas (RTBs). Plantain may also be rightfully considered as a type of cooking banana (Hegele *et al.*, 2020). Plantain production in developing countries rose to 122 million during the last three decades, the largest share (56%) of output shifted from Latin America Caribbean (LAC) to Asia. Africa harvests less than 20% of the developing country total. In the process, banana became the third most important RTB in the world surpassing sweet potato in terms of total production (HONFO *et al.*, 2020).

Conversely, the largest share (60%) of global plantain production of 30 million takes place in Sub Saharan Africa (SSA). Often planted in association with several other crops, they also provide dietary diversity. Cooking bananas and plantain remain an important source of calories for many small farm households particularly in SSA and parts of South Asia, SEA and LAC.(Arimo *et al.*, 2015).

According to Chandru *et al.* (2021), the gross value of production of plantain ranks first among food crops in sub-Sahara Africa. Worldwide, seven of the top ten plantain producing countries are in Sub-Saharan Africa, including the West African countries of Ghana,

Nigeria, Guinea and Côte d'Ivoire. It is evident that Ghana is the largest producer of plantain in West Africa with about 3.95 million metric tons in 2016 contributing about 13.1% to the agricultural Gross Domestic Product (GDP). On the other hand, Guinea recorded the lowest output of only 469,252 metric tons. Over the years, plantains from Ghana to the European market have attracted a higher premium than from other producing countries. This is because the geographical location of Ghana places the country in a position to capture the European market compared to other plantain-exporting countries such as Colombia, Ecuador, Venezuela and Costa Rica of the Latin American and Caribbean regions. This geographical advantage held by Ghana might be the reason for her consistency in increased production. Nigeria is the second largest producer with about 2.8 million metric tons, ranking sixth worldwide (Olumba and Onunka 2020).

2.7 Crop Propagation

The quality of the planting material is one of the major factors for successful crop production. In plantain, most farmers use planting material from former plantain fields, irrespective of the health status of the mother plant. It appears that farmers have no strong concept of infectious plant pests and diseases that are propagated by infested suckers. The presence, symptoms and consequences of nematode infestation are largely unknown to farmers and there is no efficient control methods used. Poor sucker quality leads to high plant losses and shortened plantation longevity with occasionally complete failure of the ratoon crop (Mekoa and Hanser 2019).

There are several ways to disinfest suckers such as hot water treatment or boiling water treatment. An alternative is the production of clean planting material from corm fragments or detached corms. If conducted correctly all methods should result in pest and disease-free

planting material with a high potential to attain high yields. However, any new technology requires field testing under farmer conditions to ensure that the materials used are of superior performance and that the technology as such is feasible for farmers. Local farmers propagate plantains using peepers, sword suckers, and maiden suckers as planting material (Dépigny *et al.*, 2019).

The little suckers that emerge from the soil are called peepers. Large suckers without lamina that resemble swords are known as sword suckers. Compared to sword suckers, maiden suckers have more "true leave" (foliage). Old fields and farms are the primary source of planting material for the production of plantains. Utilizing planting materials from former farms might lead to diseases, which lowers the output economically. Due to pests like nematodes and diseases like fusarium wilt and black Sigatoka, commercial producers have experienced catastrophic losses in their plantations (Dépigny *et al.*, 2018). Since farmers mostly rely on suckers for planting, Scientists have developed various innovations to multiply plantain suckers to make plantain materials more accessible to farmers and also to ensure the commercial production of the crop. Some of these techniques include; decapitation, bending over, split corm, the use of ex-plants, tissue culture and tissue manipulation technique (Tenkouano and Hauser 2019).

In order to allow latent axillary buds to sprout, the process entails slicing and breaking plantain corms into smaller pieces and sprouting them in damp sawdust or soil (Dzomeku, 2020). According to Ekanem and Akpheokhai (2020), suckers were planted in a hole of 0.3 m x 0.3 m x 0.3 m depth at 2.0 m x 3.0 m spacing between plants and within plants giving a population of 1,667 plants per hectare under a monocropping system in the field. Low-performing mats can be replaced by uprooting them and replacing them with a new

sucker. Ekanem and Akpheokhai (2020), conducted an experiment at the Teaching and Research Farm of Ekiti State University. The experimental trial was arranged in a randomized complete block design of four treatments replicated three times. The treatments were the different sanitation methods (boiling water, red acalypha leaves extracts, carbofuran and control) used to disinfest the suckers before planting at spacing of 2.5 m between rows, 2.5 m within the rows and 3.0 m between the replicates produced good yield.

Kilwinger *et al.* (2019) revealed that haphazard planting (not planting in rows) by the farmers in the present study encouraged the growth of weeds and provided little aeration around the plants. Weeds are considered to be the second most important constraint to plantain production. An unkempt farm can serve as the improper positioning of plantain plants in the present study might lead to overcrowding, providing very little room for aeration and causing the trapping of humid air and ethylene produced from ripening fruits (Ofosu *et al.*, 2023.). Plantain can be planted throughout the year except in severe dry season. In general, June-July is the most common period of planting. Farmers tended to receive higher prices for their produce between April and September peaking in August (Dépigny *et al.*, 2019).

This may be attributed to the long dry period between December and February. The beginning of the rainy season is normally associated with strong winds resulting in stem lodging of the plantain plants. However, the bulk of the plantains are harvested between October and December. This therefore results in the glut with its associate lower prices for plantains at this time because of excess supply to the market. Plantain production experiences seasonal glut between October and December (Udomkun *et al.*, 2021).

2.8 Agronomic Practices

There are several approaches to weed management. However, integrated weed management (IWM) which refers to the integration of several of these techniques, makes use of every appropriate approach in the most harmonious way feasible. It entails the strategic application of a variety of weed management techniques, such as herbicide combinations, crop rotation, mechanical and biological controls, and other cultural practices intended to lessen weed-related harm. This strategy acknowledges that relying solely on single-tactic management has frequently proven to be inadequate in the long run for controlling weed (Madziga *et al.*, 2020).

However, chemical fertilizer is currently very costly and sometimes not timely available and affordable in the market. Chemical fertilizer causes problems not only to the soil but also to the human health and physical environment. The possible alternative source of crop nutrients such as organic manure can be used to improve the physicochemical properties of the soil within the framework of sustainable soil management (Kanas *et al.*, 2020). Agronomic practices that reduce soil temperature, such as mulching, could therefore be expected to modify suckering. The mulch increased root dry weight that associated with increased suckering (Turner *et al.*, 2019).

Poultry manure, is the most preferred organic manure for its multi-beneficial effects on the soil and improved crop growth, pest control and yields. Mucuna, watermelon (climber) as a sustainable live mulch in conventional plantain orchard with improve rapid vegetal cover and heavy biomass, soil fertility and biological soil enhancement. However, live mulch involves, cover cropping, intercropping and under sowing which has added benefit of obtaining additional produce. Watermelon is envisaged to serve as live mulch to ameliorate the adverse impacts of moisture stress. Intercropping mostly confers positive synergy on

yields of the component crops and improvement in soil physic-chemical properties. Competition with plantains may occur (Hapsari *et al.*, 2022). Effective vegetal cover as live mulch smothered weed growth reduced competition with weeds in plantain intercropped plot. Growth retards during the dry season but availability of adequate mulch at the onset of rainy season kick starts rapid and vigorous growth resumption in plantain and thus improved plantain growth vigour.

Brown *et al.* (2017), in Southeastern Nigeria has discovered a conventional application of poultry manure in late season live mulch intercropping of plantain-watermelon production which produced high yield in plantain and watermelon.

This efficiency has created a new dimension in income generation for farmers who adopt late season plantain-watermelon intercropping. Intercropping of plantain with watermelon helped reduced moisture stress and created a favorable micro-climate for the growth and yield of plantain during the dry season. Majority of farmers do not carry out de-suckering. They believe that the more the number of plants per stool, the more the anticipated bunches to be harvested. Therefore, they accumulate non-vibrant plants with weak pseudo-stems that are sensitive to the least wind. These plants end up producing small bunches and slender fingers. Equally, dry leaves, leaf sheaths and stumps are accumulated in farms which harbor weevils, insects, birds and rodents that end up affecting Musa corms, pseudo-stem, fresh leaves and fruits (Njoku, 2021).

Toppling due to strong wind has also been reported by GASPAR (2020), as one of the main causes of pre-harvest losses in most Africa countries of plantain production. Farmers should be practicing proper propping of fruited as well as non-fruited plants to minimize the effect of the storm. Dwarf variety of plantain and those at closed spacing do not need propping

but for all tall varieties, it is required by using bamboo poles or any other supports. Propping can be done in three ways (1) supporting the tilted plants at the level of the leaf crown or under the bunch in the case of fruited plants with two crisscross dry bamboos or poles to form a tripod, (2) staking by pinning a healthy pole (2-4 m of length depending on the height of the plant) 50 cm-1 m away from the tilted plant or in between oppositely tilted plants and fastening a twine above the mid part of the plants to the poles and (3) fastening a twine on a stick of 15-20 cm and passing it in between the leaf crown to hook on the transitional peduncle (spike) and then pulling the extended part of the twine and fastening it on a stump or tree. These methods can be applied individually or two on the same plant depending on the size of the bunch and intensity of wind in a locality.

Thrashing is done to remove old, dry, diseased and senescent leaves this could reduce the disease and facilitate better light, temperature and air. However, if leaves are pruned before bunch initiation, flowering is delayed and cycle time increased. A minimum of 12 leaves is required to be retained for maximum yields. Mattocking is the cutting of the pseudostem after harvesting of bunches. After harvesting the pseudostem should be cut leaving a stump of about 0.6 m height, the left-over stump with its stored food material continues to nourish the daughter sucker (follower) till it withers and dries up. Denaveling increases the bunch weight/fruit weight and quality of fruits when the male buds is removed after the last set of fruit. This practice improves air circulation and light penetration to enhance photosynthesis, better nutrient allocation to the fruiting plants. This should be done carefully to avoid damaging the main fruit set (Meghwal and Jayachandra 2020).

2.9 Harvesting and Fruit Handling

The edible plantain bunch consists of a series of hands of plantain developed from female flowers which are attached to a thick peduncle. The number of hands per bunch and fingers per hand is determined at flower initiation by number of female flowers initiated in the pseudostem and is controlled by a variety of factors such as genome group, crop cycle, temperature, vigour of the plant and level of management. Under optimum conditions, plantain may take about nine months from planting to the first crop. This period, however, may extend to 18 months depending on weather conditions, cultivar and cultural practices (Oladimeji and Fadimu 2018). Several different external and internal fruit characteristics and indices can be used to determine plantain maturity. These include fruit diameter, age of the bunch, angularity of the fruit, length of the fruit, and peel colour. The time from when the fruit bunch first becomes visible (shooting) is recorded. Bunches can be tagged with different colored ribbons at the time of shooting. The colour of the ribbons is changed weekly to coincide with the time of shooting and subsequently the age of the bunch. A method used to determine harvest maturity is to observe the shape (fullness) and angularity of the fruit. Immature fruit is angular in cross-sectional shape and has distinct ridges. As the fruit matures, it becomes less angular and more rounded or full. The degree of roundness differs between cultivars and location of the hand on the bunch. Fruit intended for the domestic market should be harvested when the fruit shape is nearly round. Export market fruit intended for the European market should be harvested when the fruit shape is slightly angular. Other way of estimating plantain bunch maturity is to measure the length of the edible pulp portion of the fruit from the fingers in the middle hand (Adheka *et al.*, 2018).

The length should be a minimum of 15 cm for the domestic market and 18 cm for the export market. Finally peel colour is another frequently used method of assessing fruit maturity.

The peel remains green throughout growth and development of the fruit until it reaches physiological maturity. It then changes to a yellow colour during ripening where the starch will progressively be converted to sugar as ripening progresses (Diarsa and Gupte 2020). The usual method of harvesting plantains is to partly cut through the pseudostem approximately 2 m from the ground or at upper thirds with a machete. This allows the plant to bend over under the weight of the bunch. The bunch is then cut off and taken away while the pseudostem is left on the plot. This technique ensures that, bunch does not fall directly on the ground to prevent postharvest losses. Traditional banana picking operations require the cooperation of two workers, one using a machete to cut the banana bunch stalk and separating it from the pseudostem of the banana mother plant, the other putting a flexible pad on the shoulder to hold the cut banana bunch. The equipment is an eight-foot stick with steel drawbars on the top end; a high hook with the steel pull rod facing downward is used to pull down the cut pseudo-stem, and the low hook with the steel pull rod facing upward is used to support the curved pseudo-stem, which makes it possible to pick plantain bunches at a suspended height (Isoda *et al.*, 2021). The Massachusetts Institute of Technology and others have developed assisted equipment for picking bunches of bananas and plantain, and the optimized design for efficient and safe harvesting (Dépigny *et al.*, 2019).

Transporting bunches in polyethylene cover in commercial production of plantain is found to be effective in reducing the level of bruising and damage. Colour change in plantain fruit from green to yellow is the result of chlorophyll degradation. Plantain will ripen naturally at ambient tropical temperature (Ukwuaba *et al.*, 2022a). Increased production without corresponding well-developed and efficient marketing systems may amount to wastage of resources. Thus, agricultural production problems can be overcome through introducing

new technology and facilities for storage, processing and value addition as well as efficient transportation and marketing systems (Scott, 2021).

2.10 Effect of Different Rooting Hormones on Growth and Yield of Plantain

There are two main categories of plant hormones or regulators namely the natural plant hormone and the synthetic hormone. Natural plant hormones are naturally occurring organic compounds which affect the growth and development of plants. However, their effects are far from the origin of production (Karunarathna *et al.*, 2019a). In general rooting hormones, being liquid or powder, when applied properly aid in rooting of moderate to difficult to root species, accelerate root initiation, improve rooting uniformity, increase the number of roots produced and ultimately reduce shrink and rooting time. When rooting hormones and other cultural practices are combined with optimal environmental conditions, the results are high-quality, well-rooted liners (Lee *et al.*, 2019).

Synthetic growth hormones which are prepared at a standard concentration and are also referred to as growth regulators are manufactured in laboratories. Indole-3-acetic acid (IAA) and indole butyric acid (IBA) are obtained from natural plant sources, whereas naphthalene acetic acid (NAA) and Naphthalene acetamide (NAAM), 4-dichlorophenoxypropanoic acid (4-DCPPA), are obtained from synthetic sources (Opata *et al.*, 2020). Coconut water is traditionally used as a growth supplement in plant tissue culture. The wide applications of coconut water can be justified by its unique chemical composition of sugars, vitamins, minerals, amino acids, and phytohormones.

Phytohormones can directly or indirectly promote plant growth which includes gibberellins, auxins, and cytokinin. Since coconut water is rich in phytohormones and

nutrients there is a possibility, that it can be used as root promoting medium in mangrove propagation. The Philippines is also coconut producing country, coconut farmers usually produce a lot of coconut water which is normally thrown away. This study was carried out to utilize coconut water as a root setting medium to propagate (Bogale, 2018). Again, suckers generated from the technique do not grow as vigorous as sword suckers, especially when corms are split into more than four pieces. It is, therefore, necessary to develop other approaches to improve the efficiency of the split-corm technique. Plantain suckers develop from axillary buds pre-formed on the corm. Hence, stimulation of axillary bud formation on plantain corm could increase the multiplication rate of the split corm technique. Manju and Pushpalatha (2022), showed that axillary bud formation and development of plantain could be promoted when injected with 8 mL coconut water.

The optimal ratio of cytokinin and auxins is very important during the differentiation of plant tissues into roots, shoots, and flowers (organogenesis). In *in vitro* micro-propagation of plantain, high auxin: cytokinin ratios induce root formation whereas low auxin: cytokinin ratios promote shoot formation. Coconut water is a natural source of auxins and cytokinin (Opata *et al.*, 2021a). In general, treatments with coconut water from fully matured dried fruits produced the largest and the most vigorously growing plantlets (Bogale, 2018). Coconut water contains indole-3-acetic acid (IAA), the primary auxin in plants. Indole-3-acetic acid is responsible for many regulatory processes in plants particularly to plant growth and development (Waadt *et al.*, 2022). Coconut water and honey as natural hormones contain derivatives of plant hormones responsible to control growth and development at their respective part of meristematic tissues most especially the effectiveness to initiate roots in vegetative cuttings (Dunsin *et al.*, 2018a). Karunarathna *et al* (2019b), reported that the recipe of honey from a solution of required amount of hot water produces healthy and vigorous root growth hormone that is equal or better than the

commercial rooting hormone on the market. Honey has many health benefits. Honey contains many kinds of sugars, amino acids, minerals, antioxidants, and gluconic acid (Egbontan *et al.*, 2020). These chemicals give honey both antibacterial and antifungal properties, which help prevent root rot and maintain a cleaner environment for root growth. Honey might prove to be a safe, cost-effective, and easily used method to help cuttings grow adventitious roots. Honey has already been used to root some plants. Other articles in the popular literature promote honey as a rooting stimulant (Karunarathna *et al.*, 2019b).

Dunsin *et al.* (2018) also reported on related research article 'Effects of alternative hormones on the rooting ability of *Parkia biglobosa* cuttings using honey'. Water in its composition does not contain any known hormone but it has been increasingly recognized as playing key role in protein-ligand interactions, osmotic stress sensory and signaling mechanisms. Water is characterized by the thermodynamics associated with the binding pathway (Zheljazkov *et al.*, 2020). There is a correlation between plant hormones and the major functions of water and other abiotic factors such as drought, salinity, heat and cold have profound effects on plants growth and development. Abiotic stresses further cause bud dormancy, leaf senescence, and organ abscission, which water holds primary role to effective function of a respective hormones. For instance, water molecules, can be displaced, replaced or retained in in the binding capacity of receptor that recognized plant hormones bind to their receptors and trigger a response. Auxin, for example can increase the rate of respiration in root, potentially leading to enhance water absorption (Waadt *et al.*, 2023).

In order to reduce risks of transmission of pests and disease organisms from existing orchards to new orchard, sanitation of propagules through exposure to heat for relatively

long time, immersion of propagules in boiling water for 30 seconds as well as paring and dipping of propagule in red acalypha plant extract for 20 minutes have been strongly recommended for a successful plantain orchard. The use of pest free propagules in the establishment of new plantain orchards, replacement of lost stands in existing fields and expansion old plantation accrues a lot benefits to farmers and also promote healthy rooting system for better plant development and crop yield. The study revealed that, the growth parameters measured among the control treated plants differed significantly from the boiling water and acalypha treated plants. The delay in some few treated plant growth among the boiling water and acalypha treated plants might be an indication of harsh heat treatment and stress due to wound from paring yet overall performance of treated plantain were highly successful (Yong *et al.*, 2019).

2.11 Effect of Rooting hormones and Dipping Time on Plantain Growth and Yield

Research conducted by Moyin-Jesu (2019) has proven that, the use of plant growth regulators has resulted in outstanding achievements in several fruit crops with respect to growth and development, yield and fruit quality. Fruits are considered high value produce from plant and even small modifications in production efficiency, product quality or enhanced appeal have the potential to significantly increase product value. Mango (*Mangifera indica* L.) stones presoaked with gibberellic acid (GA₃) at 100 ppm recorded maximum (85.67%) germination followed by KNO₃ (81.66%). While minimum germination percentage (63.33%) was observed in the control (no treatment). A preharvest treatment with gibberellic acid (GA₃) extended the storage life of the fruit by delaying both black spot development and fruit softening (Lomo-Mensah, 2021).

However, the dipping time of plantain of rooting hormones affects growth and yield, as different hormones and their concentrations can promote or inhibit growth, and the duration

of the dip can influence the extent of cell damage or uptake, significantly impacting the number of suckers, plant height, and ultimately, fruit yield (Abdel-Rahman *et al.*, 2020). Excessive dip times can lead to cellular damage and even death of the plant material when the intercellular space is widely increased while optimal short duration with appropriate plant growth regulators can improve sucker proliferation and yield (Zamrodah, 2019). Studies on plantains show that the duration and type of hormonal treatment are crucial. By improving sucker production and the overall vigour of the plant, hormonal treatments with optimized dip durations can contribute to increased fruit yield, though the specific hormone and application method are critical.

The difference in dipping time in plant hormones can indeed impact growth and yield in plantain corm propagation. The dipping time or duration of exposure to plant hormones can influence the response of plantain corms. For example, a short dip or quick dip with certain plant hormones can result in earlier emergence of lateral shoot and a higher number of suckers effective depending on the concentration of the treatment (Hegele *et al.*, 2020). The application of these regulators even indirectly through corm treatments lead to higher yields. Different plantain clones or cultivars may respond differently to hormone treatments and dipping times (Guleria *et al.*, 2021).

Research conducted by Medford *et al.* (2019), on the effect of rooting hormone, concentration of treatment and treatment time, reported that the interaction effect between rooting promoters and concentration did not affect the rooting percentage, average number of roots and total root length. However, it was observed that rooting hormones concentration was key in affecting rooting hormonal activities, followed by the type of rooting hormones and the treatment time or dipping time (duration) has little effect on the overall processes: growth and development, differentiation, encompasses modifications ranging

from subtle changes in cellular metabolism to physiological and morphological modifications (Guleria *et al.*, 2021).

2.12 Effect of rooting hormones and dipping times on plantain fruit quality

Plant hormones signal molecules produced within the plant, and occur in extremely low concentrations. Phytohormones determine the formation of flowers, stems, leaves, shedding of leaves, and development and ripening of fruits. They shape the plant, affecting seed growth, time of flowering, sex of flowers, senescence of leaves and fruits formation. The use of growth regulators has become an important component of Agro-technical procedures for most of the cultivated cuttings.

Dipping time or duration for rooting hormones on corms affects the fruit quality is indirect and complex as the primary effect of the rooting hormones. However, rooting hormones stimulate root development not directly improve fruit quality. Instead, the success in rooting can lead to more vigorous and strong plant resulting from successful root development which eventually lead to better quality that produce high yield and potential better yield over long term. Although specific dipping time will influence how well the plantain adapts and grows. Some plant treatments have shown that dipping time in certain cutting can impact fruiting and cormlets (plantlets) production as precursor to fruiting. In essence, the dipping time for some rooting hormones on a corm influence the success of the initial planting stage, which then impact the subsequent growth and eventual fruit production (Davies and Hartung 2022).

The exogenous application of bioregulators act as a powerful tool not only for enhancing growth, productivity and quality of fruits but also in combating the ill effects generated by

various biotic and abiotic stresses in plants in the near future. It aids to enhance potential crop yield and alleviate hunger and malnutrition in the ever-increasing human population of the world (Appiah and Mensah 2023).

Ekanem and Akpheokhai (2020), reported on the prospects of implementing sucker sanitation technology a safe environment for rooting hormones to contribute to the quality and yield of plantain production. Research on red acalypha leaves were sun dried and milled. 90 grams of milled acalypha leaves were soaked in 10 litres of water for 20 minutes. This was done to ensure adequate suspension of the milled leaves in water. Suckers were pared and dipped in the acalypha solution for 20 minutes after which they were removed and allowed to dry for another 10 minutes before planting was done. For the boiling water dipping procedure, water was put in a one-sided opened metal drum which was placed over an open fire. The water was allowed to boil before dipping pared suckers for 20 seconds. At the expiration of the set time the suckers were removed and allowed to access fresh air for an hour before planting. For the chemical procedure, 3 grams of furadan (carbofuran) was mixed with the same quantity of sand and applied into the dug holes before planting the suckers.

All treated plants flowered after a year of establishment. However, acalypha treated and boiling water treated plants had the shortest days to flowering and to harvest. The shortest day to fruit filling, as well as highest number of fingers and highest bunch yield were recorded among acalypha treated plants. The lowest bunch yield was recorded in the control plants. The use of pest free propagules in the establishment of new plantain orchards also promote healthy rooting system for better plant development and crop yield. It was noted in this study that the growth parameters measured among the control treated plants differed significantly from the boiling water and acalypha treated plants (Madziga *et al.*, 2020).

Yamoah *et al.* (2021) in similar research on factors influence adoption of organic farming practices, plantain yield was greatly enhanced in acalypha and boiling water treatment. Both treatments had shortest days to flowering and fruit filling, highest number of fingers and highest bunch yield.

Meghwal and Jayachandra (2020) reported the presence of carbohydrate in the leaf extract of acalypha. Carbohydrate is noted to have numerous roles in living cells such as the storage and transport of energy (starch and glycogen) and structural components (cellulose) in plants. Similarly, Tenkouano and Hauser (2017) in a study on plantain bunch yield and root health response to combinations of physical, thermal and chemical sucker sanitation measures had earlier noted that boiling water treatment contributed to faster growth, reduced incidence and severity of pests and diseases as well as physiological stimulation of plantain growth. All of these culminated into greater bunch yield (Guleria *et al.*, 2021).

CHAPTER THREE: MATERIALS AND METHODS

3.1 Experimental Location and Description

The experiment was carried out at the research field of Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Asante Mampong Campus. Asante Mampong is located 51 kilometres at a bearing of North - East from Kumasi in the Ashanti region of Ghana. Asante Mampong Municipal is located in the Northern part of Ashanti Region and Asante Mampong is its capital town. Mampong municipal shares a boundary with Sekyere south district in the south, Sekyere central district in the east and Ejura Sekyedumase in the north. The Mampong municipal is located (Lat. 07°, 04'N; Long. 01°, 24'W) (Atakora *et al.*, 2023).

The area has bimodal rainfall pattern with the major rainy season occurring from April to July and minor rainy season from September to November. Between the two seasons is a short dry spell in August. The mean total annual rainfall in the area is 094 mm to 1200 mm with temperature range of 22/23 °C – 30 °C (Meteorological Service Department Kumasi – Ashanti, 2005). Humidity is high averaging about 85 % in the southern districts and 65% in the northern part of the region. The potential evapotranspiration (PET) is estimated at 1450 mm/y (Kotei *et al.*, 2013).

The average humidity during the wet season is typically high (86 %) and falls to about 57 % in the dry period. The soil at the experimental site is classified by the FAO legend as Chromic Luvisol and locally as the Bediesi series (Kotei *et al.*, 2013). The soil is sandy loam, well drained with thin layer of organic matter. The pH ranges from 6.5-7.0. The soil type is the savannah Ochrosol formed from the Voltaian sandstone of the Afram plains. Texturally, the soil is friable with a thin layer of organic matter and is deep and brown-

sandy loam and well-drained. It however has a good water holding capacity. Due to continuous cultivation of the land, the nutrient level has declined and for that matter, the nutrient level is supplemented with the addition of poultry droppings to support deep-rooted plants. The field is good for the production of roots and tuber crops, vegetables, legumes and cereals (Essilfie *et al.*, 2017).

3.2 Experimental Design and Treatments

3.2.1 Experimental design

The experimental design used was a 3 x 3 factorial experiment arranged in Randomized Complete Block Design (RCBD) with nine treatments and each replicated three times. There were two factors namely; (A) Dipping time [(i) Quick dip, (ii) 2-hour dip and (iii) 4-hour dip] and (B) Rooting hormones [(i) coconut water, (ii) honey and (iii) water].

3.2.2 Treatments

The treatment combination as shown in table 3.1

Table 3.1: Treatment combinations

Treatment	Dipping time	Rooting hormones
T1	Quick dip	Coconut water
T2	2 hours dip	Coconut water
T3	4 hours dip	Coconut water
T4	Quick dip	Honey
T5	2 hours dip	Honey
T6	4 hours dip	Honey
T7	Quick dip	Pipe borne water (control)
T8	2 hours dip	Pipe borne water (control)
T9	4 hours dip	Pipe borne water (control)

3.3 Source of Plantain Plantlets (Minisetts using the Split corm technique) and

Preparation

Maiden plantain suckers derived from ‘Apantu’ plantain cultivar (False Horn) were obtained from CSIR-Crops Research Institute at Fumesua, Kumasi in the Ashanti Region of Ghana. These types of ‘Apantu’ plantain suckers are considered the most productive source of materials for establishing new plantings (Dzomeku *et al*, 2020). The harvested plantain suckers were kept under shade before mechanical preparation. The pseudostems of the suckers were detached completely; close to the corm and the leaf sheaths were also removed with a sharp knife to expose the buds on the corm. The corms were then subjected to paring, which involved cleaning the corm by cutting off the roots. This paring process also ensured that soil-borne microorganisms, especially root nematodes and stem borers, were also eliminated (Mensah and Kotei 2019).

The pared corms were then subjected to mechanical manipulation by carefully removing all leaf sheaths around the collar with a sharp knife. When the apical meristem of the corm was exposed, the corms were washed under running tap water to further remove any foreign materials. The corms were cut across into six or more at the terminal part by splitting them completely according to their sizes to obtain the minisetts. The minisetts were weighed on an electronic weighing scale to ensure relatively uniform sizes; an average mass of 300 grams for a corm was realized to reduce the level of bias and errors. They were air-dried to reduce the moisture content.

Wood ash which was locally available and easy to apply with its related benefits was used in place of synthetic fungicide to treat the minisetts against soil microbes and other pests. Water was added to the wood ash and continuously stirred to produce a uniform solution.

This was applied to the minisetts. The salt in the wood ash killed bothersome pests like snails, slugs, and some kinds of soft-bodied invertebrates. The nutrient and minerals in the wood will be much higher if it is primarily from hard wood whilst soft wood ash provide fewer minerals and nutrient. Wood ash retains most of the major plant nutrients such as potassium, phosphorus, magnesium and calcium compounds elements except nitrogen and has liming properties owing to the high content of metal oxides and hydroxide (Hannam *et al.*, 2018).

3.4 Rooting Hormones Preparation

3.4.1 Fresh coconut water

An equal volume of 2L of coconut water obtained from a local farmer and of the same age was measured into each of the three (3) opened transparent rectangular cylinder all measured 40 cm x 30 cm x 20 cm by volume (24,000 cm³).

3.4.2 Honey

To ensure the reliability of the source of the honey, it was purchased from accredited certified pure honey sales point at the CSIR of Forestry Research Institute of Ghana (FORIG) in Kumasi. One and half tablespoonful (22.5 mL) of honey was measured into one cup (236.6 mL) of warm water, to break the cohesion of the viscosity to enhance dilution (www.thespruceeat.com). The number of tablespoons of honey was increased according to the volume of dilution factor of solution for the number of minisetts. The solution was allowed to cool before dipping the minisetts according to the dipping time.

3.4.3 Water

Pipe borne water was used as a control treatment so that other treatments and their respective dipping rate could be compared to ascertain the efficacy of the other treatments during analysis. The same sizes of containers dimensioned 40 cm x 30 cm x 20 cm by volume (24, 000 cm³) for the other treatments were use to receive water. It was filled half way (12,000 cm³) of the volume of the rectangular cylinder in other to accommodate the minisetts and water spillage.

3.5 Pre -Planting Activities

3.5.1 Land Preparation

The experimental field was cleared using cutlass, hoe and axe. Chainsaw was used to cut down big trees. The cut logs of big trees were rolled to a safe place to maximized space. The debris were left to dry and later burnt. Subsequently, the stumps, unburnt branches and twigs were removed with the help of pick axe and other diggers such as earth chisel to ensure smooth operation during planting activities. Line and pegs were used to mark out the field. Tape measure was used to measure 3 m at all the four corners; around the field and two alleys measuring 3 m was left between each of the blocks. The tape measure was used to measure and mark the planting distances of 2 m in-between rows and 2 m between plots. The line and pegs were subsequently used to mark out the spot to be planted. Pegs were then driven into the soil at all the spots and suckers were finally planted at all the spots.

3.5.2 Fencing of Experimental Field

Wooden slabs and wooden poles were carefully selected and used for the fencing. An extra space of 3 m was measured away from the research field, to create a walkway around the field. Vertical poles of about two and a half meters (2.5 m) high where erected in an equal

interval in all the dug-out holes of about 40 cm deep using the earth chisel. The poles were aligned and the wooden slaps were used to brace the sides of the poles, tightly fastening together with nails to ensure that the horizontal spaces created can restrict entering of stray animals and provides security for the suckers. All the sharp and rough edges of the poles and the wooden claps were properly trimmed for environmental safety. A sizeable gate to provide easy access to the research field was created and securely locked by a padlock to restrict intruders into the field.

3.6 Nursery Preparations and Transplanting of Plantain Plantlets

The treated plantain corm minisetts were raised in a humidified chamber (propagator) filled with sawdust as substrate and covered with transparent polythene sheets to create a microclimate to induce sprouting in March 2023. The corms sprouted at their lateral buds within three to four weeks in the chamber and the sprouts were carefully detached to the nursery site for nursery managements and later transplanted to the main field. Transplanting of plantain plantlets to the main field was done in 23rd July 2023 with planting distance of 2 m x 2 m both within rows and in-between rows. Earth chisel was used to dig a planting hole, measured 30 cm x 20 cm of depth and width respectively whilst sharp knife was used to remove the nursery bag from one side and the ball of soil around the sucker was gently lowered into the hole. The top soil was filled back and firmed around the plantlets. There were eighty-one (81) plantain plantlets for the entire field with each block having twenty-seven (27) transplants. Each block was made up of 9 plots and each plot had three (3) plantain plantlets.

Data collected on the phenology, vegetative growth and yield and yield components were done one month after transplanting

3.7 Agronomic Practices

After planting some post planting activity such as pruning of dried leaves, to serve as mulch was carried out as the plants grow. Supplementary irrigation was also done every three days except days that it rained at the early plant growth stage. Three filled watering cans were applied to the twenty-seven suckers per block to prevent transplanting shock. Weeding was done two times to prevent competition for nutrients. Proper farm sanitation was maintained to ensure free incidence of pest and diseases. No incidence of disease and pest was witnessed during the entire period of planting to harvesting.

3.8 Data Collected

- ***Days to 50% fruiting***

The days to 50 % fruiting was determined by counting the number of days from the day of planting to the day the inflorescence emerged and the mean estimated.

- ***Days to fruit maturity***

The days to fruit maturity was estimated by counting the number of days from the day of planting to the day of harvesting of fruits and the mean recorded.

- ***Number of leaves per plant***

The total number of leaves from the mother plant was physically counted from the 6th month after planting until the 9th month and their means recorded. This parameter was determined at one-month interval.

- ***Number of suckers around each mother plant***

The number of suckers around each mother plant was counted and recorded from the 6th month after planting to the ninth month at one-month interval and their mean recorded.

- ***Plant height***

The height of three suckers around each of the mother plant were randomly selected and tagged was measured from the soil surface to the emergence point of the youngest leaf using the meter rule. The mean height of sucker was recorded from the 6th month after planting till the 9th month at a month interval.

- ***Height of mother plant***

The height of the mother plant was determined by measuring the height of the pseudostem with a meter ruler from the soil surface to the emerging point of the youngest leaf.

The mean height of the mother plant was calculated and recorded. The height of the plant was measured from 6 months after planting till the 9th month at one-month interval.

- ***Stem girth***

The girth of the mother plant was measured using a measuring tape stretched around the pseudostem at the height of 15 cm from the base to ensure uniform reference point. The mean girths determined was estimated. The stem girth was determined at the 6th month after planting at one-month interval till the 9th month.

- ***Number of suckers per plot at harvest***

The total number of suckers per plot at harvest were physically counted and the mean recorded.

- ***Number of leaves per plant at harvest***

The total number of fresh leaves per mother plant was physically counted at harvest and the mean recorded.

- ***Number of fingers per bunch***

The total number of fingers per bunch were physically counted as arranged from the lower layer to the upper layer and the mean recorded.

- ***Bunch weight per plot at harvest***

The fully matured bunch per plot was weighed after harvesting using Westinghouse electronic scale and the weight value in kilogram (kg) was recorded. Bunches with fully filled fingers and change in peel colour from green to pale green were those harvested.

- ***Bunch length at harvest***

The length of fully matured bunch per plant was measured from the base to the tip along the outer curve using a tape measure and mean estimated.

- ***Bunch stalk diameter***

The diameter of the bunch stalk close to the first hand was measured from the widest point after harvesting using a Vernier caliper and the mean expressed in centimeter.

- ***Bunch yield (t /ha)***

Bunch yield per plot on three plants were determined by measuring the weight of the bunches using Westinghouse electronic scale after harvest and the weight value in kilogram (kg) was divided by net plot area. The yield of the plantain bunch was determined using the formular below;

$$\text{Yield of Plantain (t /ha)} = \frac{\text{Sum of Bunch Masses (kg)}}{\text{Net Plot Area (m}^2\text{)}} \times 10,000\text{m}^2/\text{ha}$$

Note: 1 hectare is equivalent to 10,000 m²

3.9 Data Analysis

The data collected were subjected to Analysis of Variance (ANOVA) using GenStat Release 18.1 Statistical Package. Significant differences between means were separated and compared with Tukey's honestly significant difference (HSD) at 5% level of probability. Correlation analysis between the vegetative growth, yield and yield components of plantain was carried out.

CHAPTER FOUR: RESULTS

4.1 Weather conditions at the Experimental sites

Appendix 1 shows the weather conditions at both the nursery and field experimental site for the experimental period. The total monthly rainfall of 1,571.7 mm was recorded from March to November 2023 with peak monthly rainfall of 286.4 mm recorded in October. The mean monthly temperature ranged from 21.8°C to 33°C within the period of March to November, 2023. The average highest relative humidity from March to November, 2023 was 90.9% and the lowest with same period was 64.3%. The highest (33.8°C) daily temperature was recorded in March 2023.

4.2 Phenology

4.2.1 Days to 50 % fruiting and maturity

Table 4.1 shows significant difference ($P \leq 0.05$) among the rooting hormones in number of days to 50% fruiting. Water recorded the highest mean value of (184) in number of days to 50% fruiting, followed by honey (156) days and the lowest number of days was recorded in coconut water (141) days.

Table 4.1 shows the days to fruit maturity as influenced by rooting hormones and dipping time. The coconut water used significantly lower ($P \leq 0.05$) number of days to fruit maturity of (209) compare to honey and water which used longer days thus; (241) in 2-hours and (275) to mature in 4 hours-dip respectively. In the case of dipping time there were no significant ($P \geq 0.05$) differences among the treatments in days to fruit maturity. The interaction among the rooting hormones and dipping time was significantly different ($P \leq 0.05$) among the treatments in days to fruit maturity. The interaction between water and 2-

hour dip used a significantly ($P \leq 0.05$) higher number of days (275) to fruit maturity than the coconut with 4-hour dip which matured with least number of days (209).

Table 4.1 Number of days to 50% fruiting and days to fruit maturity as influenced by different rooting hormones and dipping time

Rooting hormone	Number of days to fruiting				Number of days to maturity			
	Dipping time				Dipping time			
	Quick dip	2 hours	4 hours	Mean	Quick dip	2 hours	4 hours	Mean
Honey	156	157	156	156	236	241	240	234
Coconut water	132	153	138	141	219	221	209	216
Water	176	187	189	184	247	275	265	262
Mean	154.70	165.70	161		234	246	238	
CV (%)	9.87				7.06			
Rooting hormone (RH)	HSD (0.05) = 15.83				HSD (0.05) = 16.88			
Dipping time (DT)	HSD (0.05) = NS				HSD (0.05) = NS			
RH x DT	HSD (0.05) = 27.42				HSD (0.05) = 29.23			

CV = Coefficient of variation; HSD = Honestly significant difference at 5%

4.3 Vegetative Growth

4.3.1 Plant height of suckers around each mother plant

From Figure 4.1 coconut water recorded significant ($P \leq 0.05$) difference in plant height over water from the 6th month through to the 9th month. However, there were no significant differences among dipping time in plant height of suckers for the entire cropping period. Coconut water recorded the highest height of suckers around the mother plant thus; 16 cm, 29 cm, 72 cm and 116 cm whilst water recorded the least height of suckers of 9 cm, 20 cm, 55 cm and 76 cm from the 6th months of planting to the 9th months for coconut water and water respectively. The interactions effect showed no significant difference.

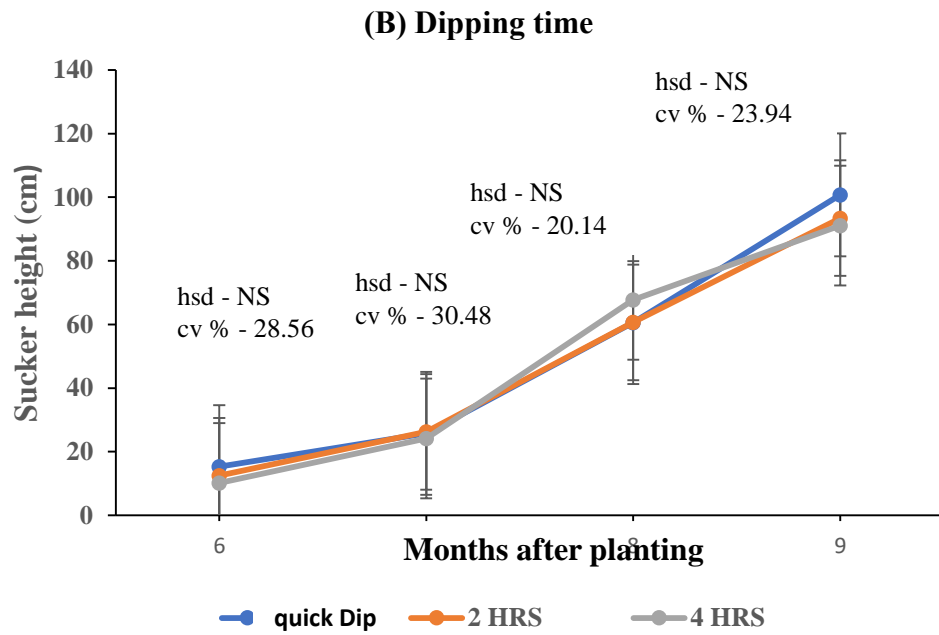
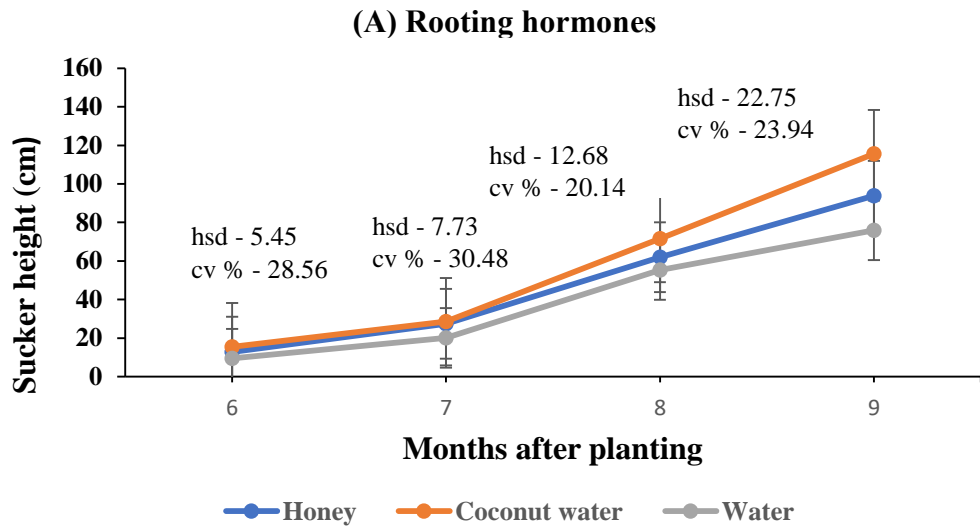


Figure 4.1a: Height of suckers as influenced by rooting hormones and dipping time

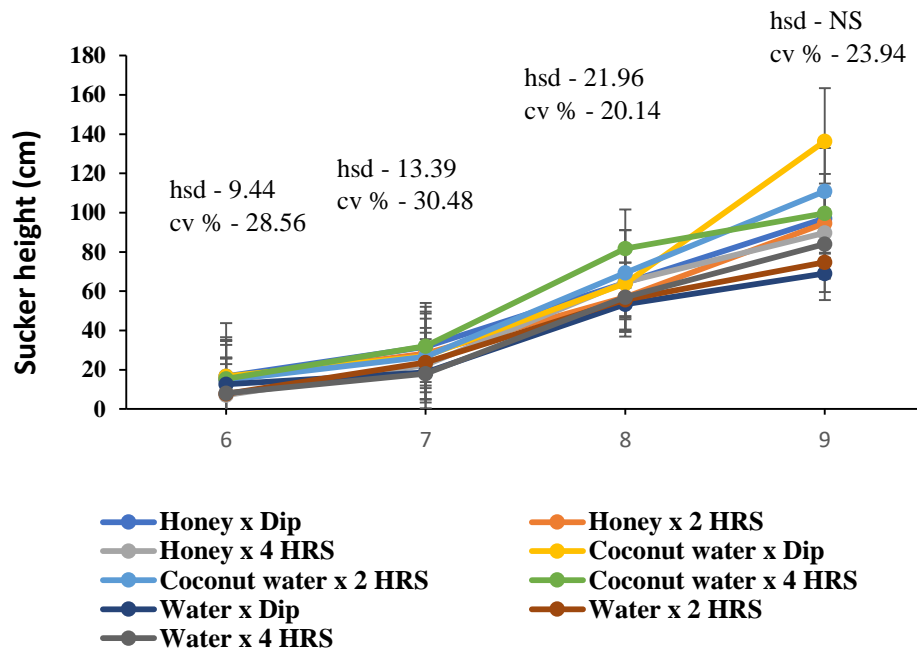


Figure 4.1b: Height of suckers as influenced by the interactions of the rooting hormones and dipping time

4.3.2 Height of mother plant

Figure 4.2 shows height of the mother plant as influenced by rooting hormones and dipping time. Both coconut water and honey recorded a significantly ($P \leq 0.05$) greater effect than water from 6th month to the 8th month after planting. At the 9th month no significant differences ($P \geq 0.05$) occurred among the honey, coconut water and water. However, dipping time did not show significant difference ($P \geq 0.05$) between the treatments at the 6th and 7th months. At the 8th month after planting, 4-hours dipping time showed significant difference ($P \leq 0.05$) than the 2-hour and quick dip. At the 9th month after planting both 4-hour dip and 2-hour dip showed a significant difference ($P \leq 0.05$) than the quick dip. The HSD test among the groups of interactions showed no significant difference yet coconut water indicate increase in means values compare to the treatment combinations of honey and water across the period of studies.

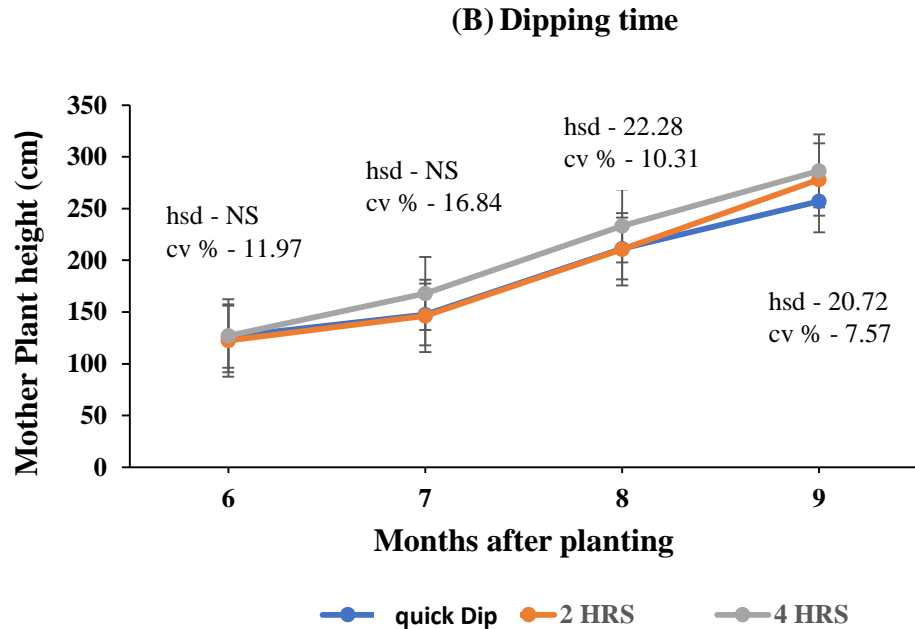
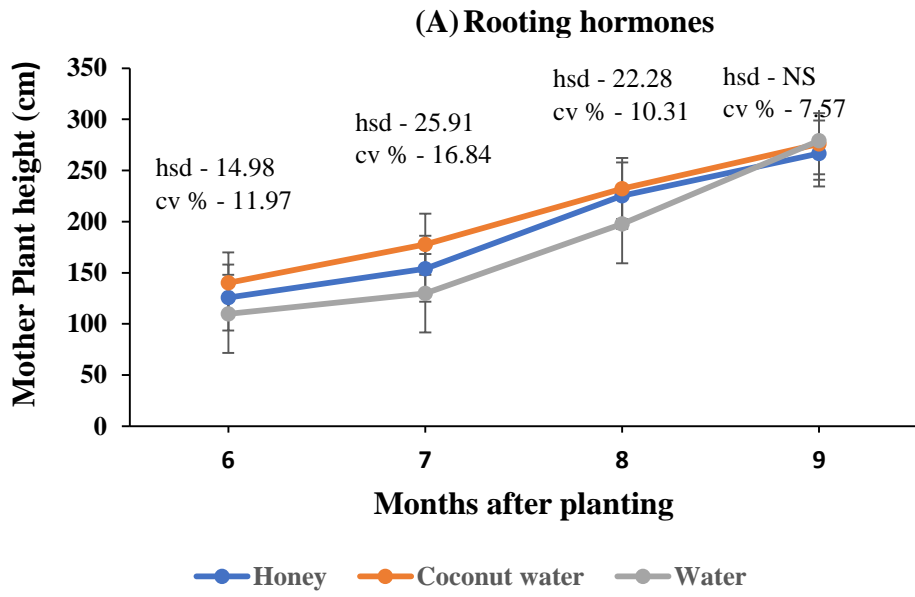


Figure 4.2a: Plant height of mother plant as influenced by rooting hormones and dipping time

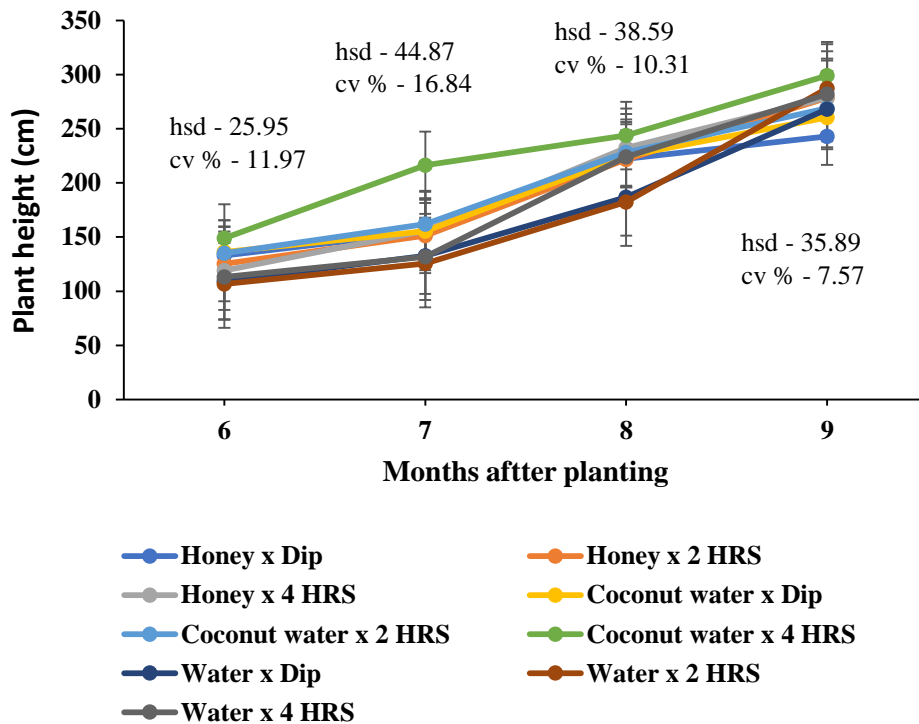


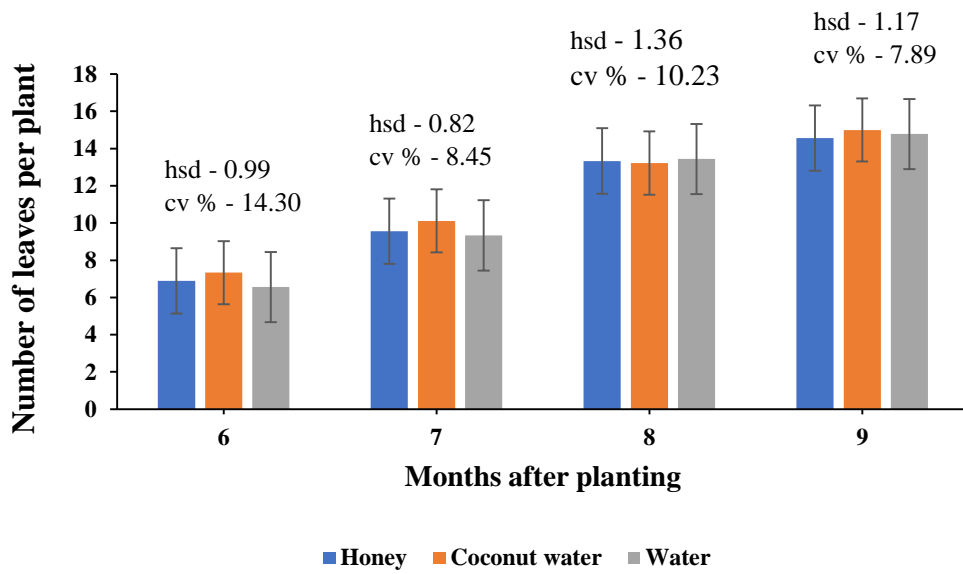
Figure 4.2b: Plant height of mother plant as influenced by the interactions of the rooting hormones and dipping time

4.3.3 Number of leaves per plant

Figure 4.3 shows the number of leaves per plant as influenced by rooting hormones and dipping time from the 6th month to the 9th month after planting. There were no significant ($P \geq 0.05$) differences among the treatment means.

There was a general trend of gradual increase in number of leaves per plant for different dipping time although there were no significant differences ($P \geq 0.05$) among quick dip, 2-hour dip and 4-hour dip. There were no significant differences among the interaction of rooting hormones and dipping time in number of leaves per plant.

(A) Rooting hormone



(B) Dipping time

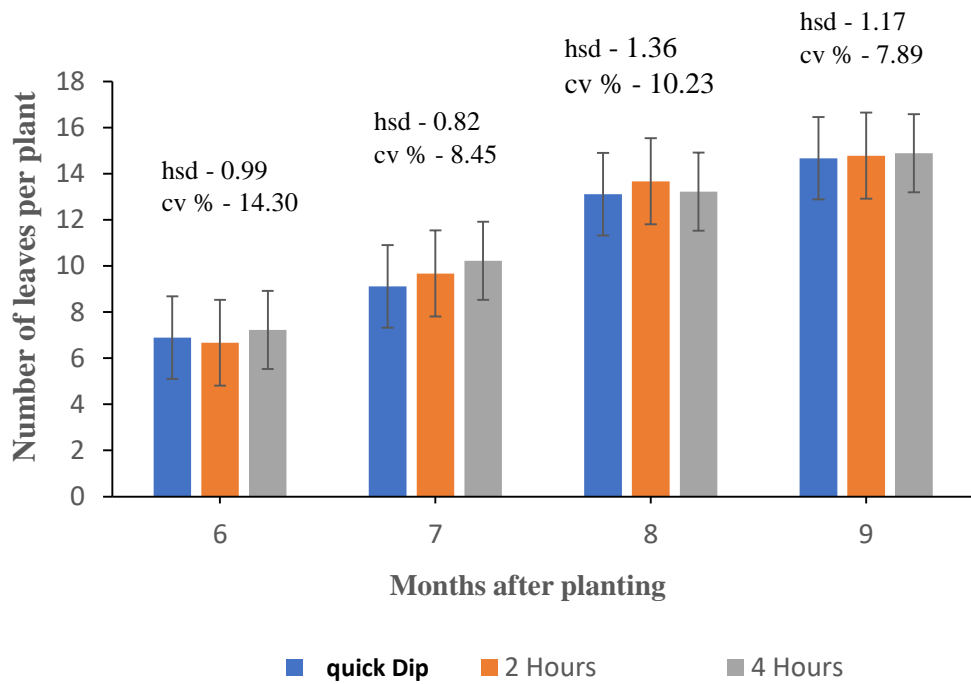


Figure 4.3a: Number of leaves per plant as influenced by rooting hormones and dipping time

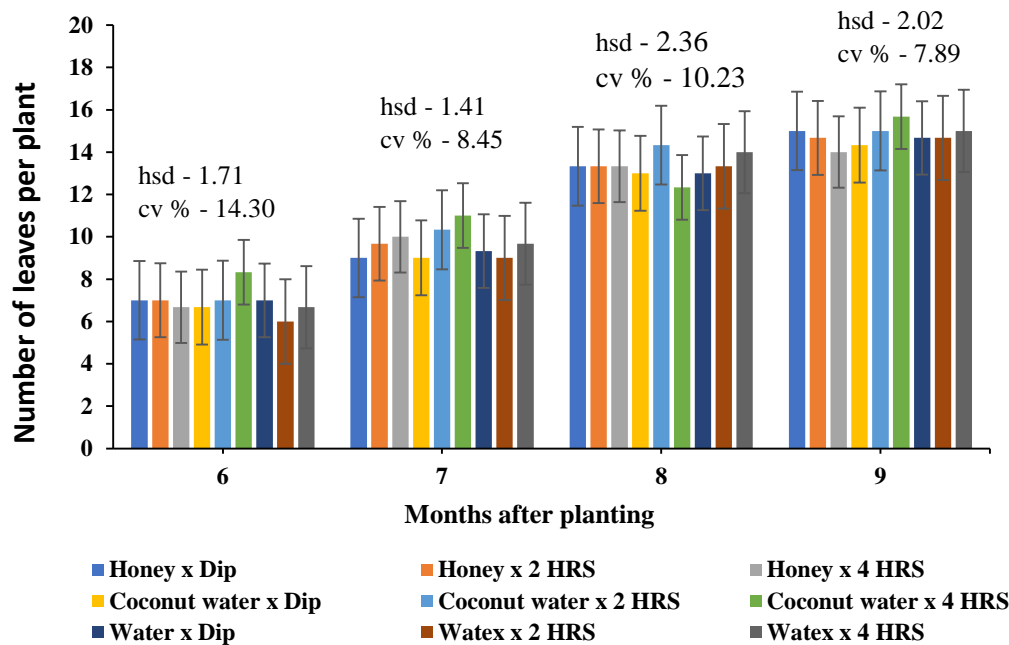


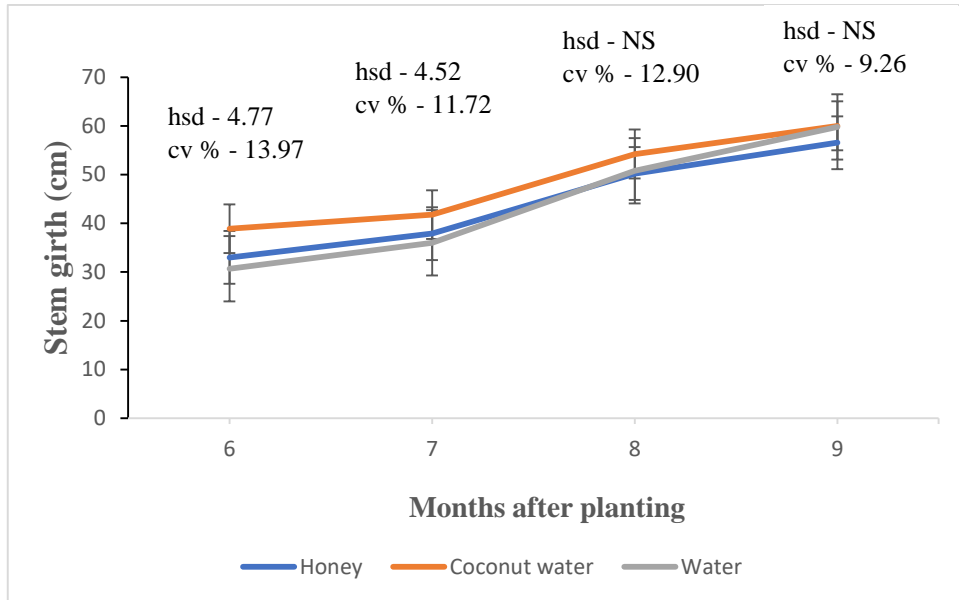
Figure 4.3b: Number of leaves per plant as influenced by interactions of rooting hormones and dipping time

4.3.4 Stem girth

Figure 4.4a shows the effect of rooting hormones and dipping time on stem girth. At 6th and 7th months after planting, coconut water and honey were significantly ($P \leq 0.05$) different from ordinary water in stem girth thus; 39 cm, 42 cm; 33 cm, 38 cm for coconut water and honey as against ordinary water of 31 cm and 36 cm for the 6th and 7th months stem girth respectively. From 8th and 9th month after planting no significant ($P \geq 0.05$) differences occurred among the rooting hormones treatment in stem girth. There were no significant differences ($P \geq 0.05$) among the various dipping time in stem girth from the 6th to 9th month after planting. The treatment interaction showed significant difference ($P \leq 0.05$) with 4-hour dip of coconut water having the widest stem girth from the 6th month to the 9th month after planting thus; 41cm, 43 cm, 55 cm and 59 cm and honey with quick dip producing the lowest stem girth at the 8th month after planting thus; 47 cm. The honey with 2-hour dip produced significantly ($P \leq 0.05$) lower stem girth of 55 cm at the 9th month

after planting compared to other interaction treatment of rooting hormones and dipping time (Figure 4.4b).

(A) Rooting hormone



(B) Dipping time

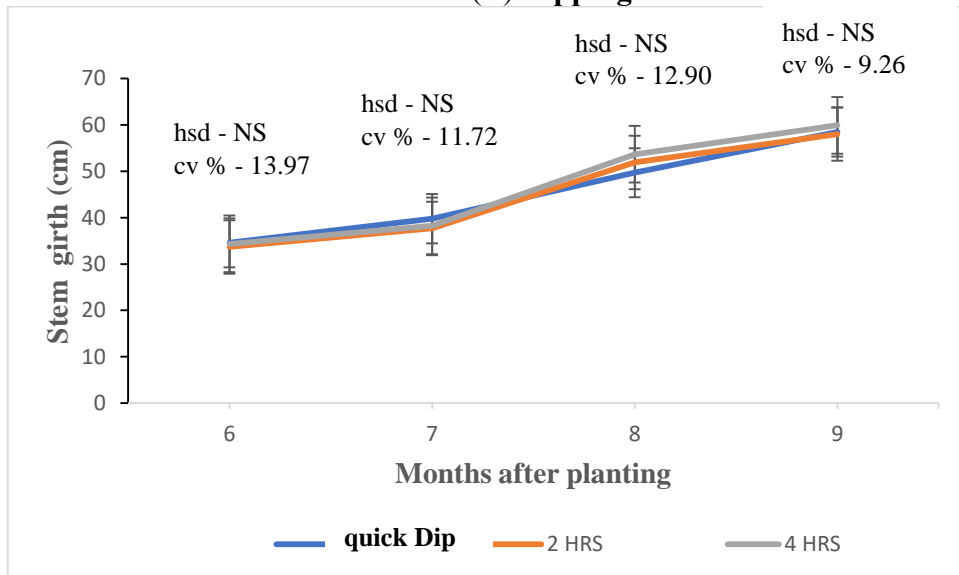


Figure 4.4a Stem girth as influenced by rooting hormones and dipping time

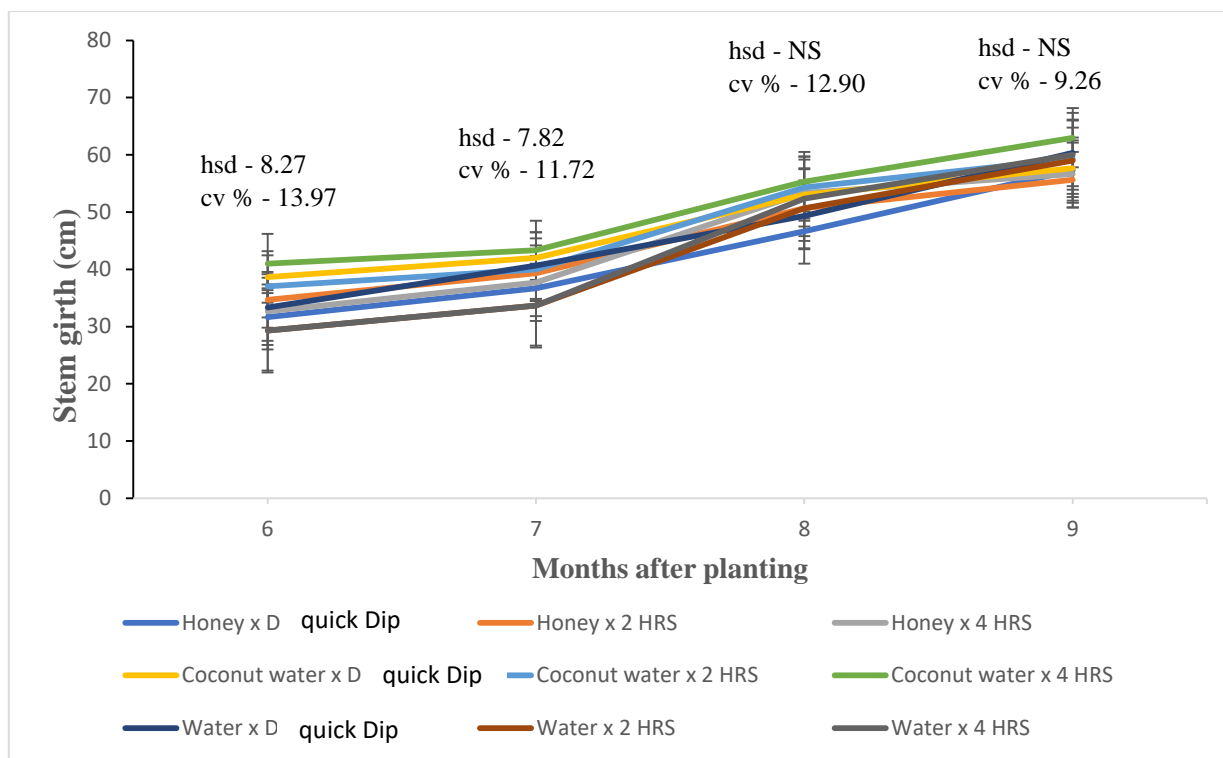


Figure 4.4b Stem girth as influenced by the interaction of rooting hormones and dipping time

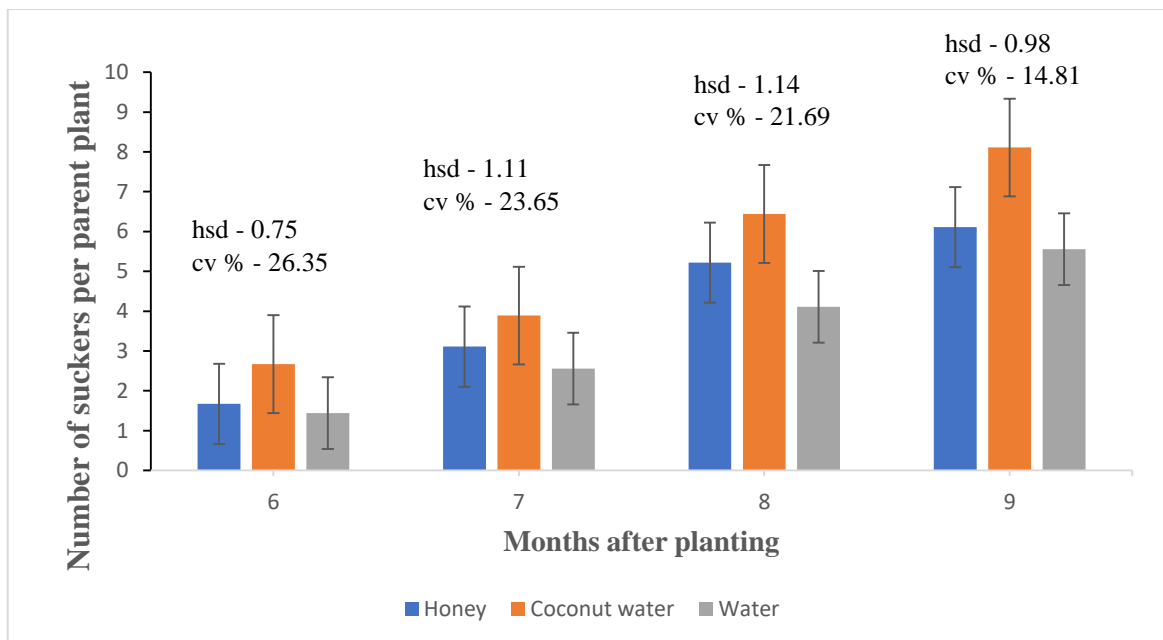
4.3.5 Number of suckers per parent plant

Figure 4.5a shows the effect of different rooting hormones and dipping time on number of suckers per parent plant. There were significant differences ($P \leq 0.05$) among the coconut water, honey and water in number of suckers per parent plant from the 6th month after planting to the 9th month. There was a general trend of increase in mean number of suckers per plant in dipping time with the 4 hours dipping recording the maximum mean (2 and 4) number from the 6th month to the 7th month after planting respectively. The quick dip recorded the least mean (2, 3, 5 and 6) number of suckers per plant for the entire cropping period. There were however no significant differences ($P \geq 0.05$) among the various dipping time in the number of suckers per plant (Figure 4.5a).

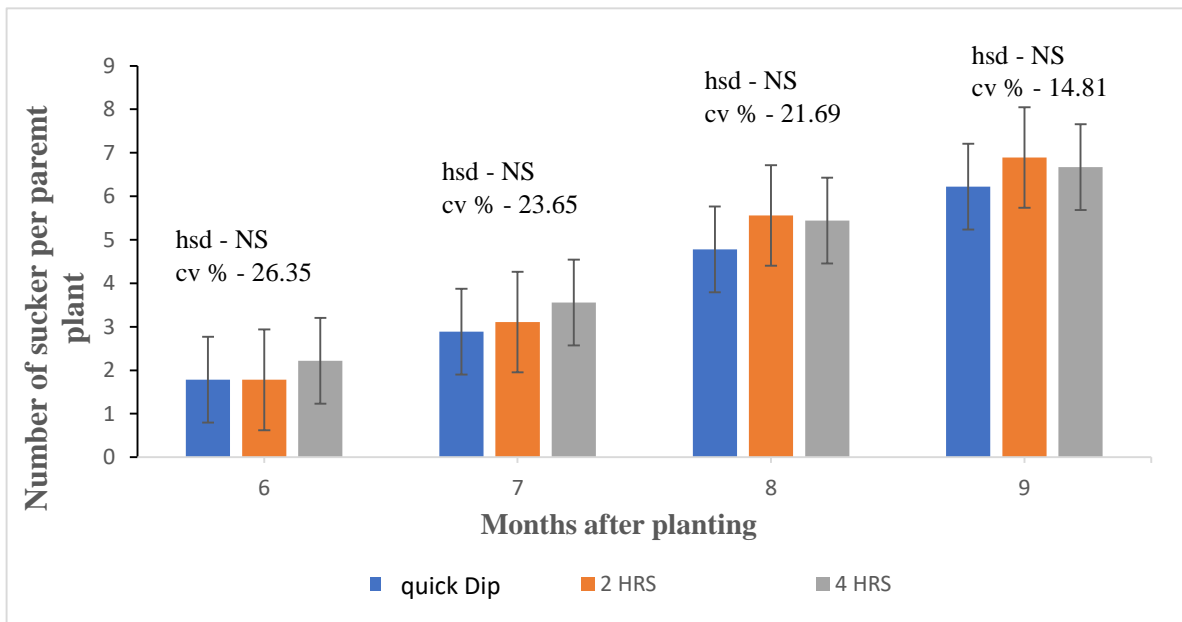
The treatment combination in Figure 4.5b shows an increase in mean number of suckers per plant. The interaction between coconut water with 4-hour dip produced significantly highest mean (3 and 4) number of suckers per plant from 6th month after planting to the 7th

month than other interaction treatments (Figure 4.5b). The interaction between the coconut water with 2-hour dip followed by coconut water with 4-hour dip and coconut water with quick dip produced significantly greater number of suckers per plant from the 8th month after planting to the 9th month. The interaction between the water and the quick dip produced the lowest mean (3 and 5) number of suckers per plant from the 8th month after planting to the 9th month.

(A) Rooting hormones



(B) Dipping time



(B)

Figure 4.5a: Number of suckers per plant as influenced by rooting hormones and dipping time

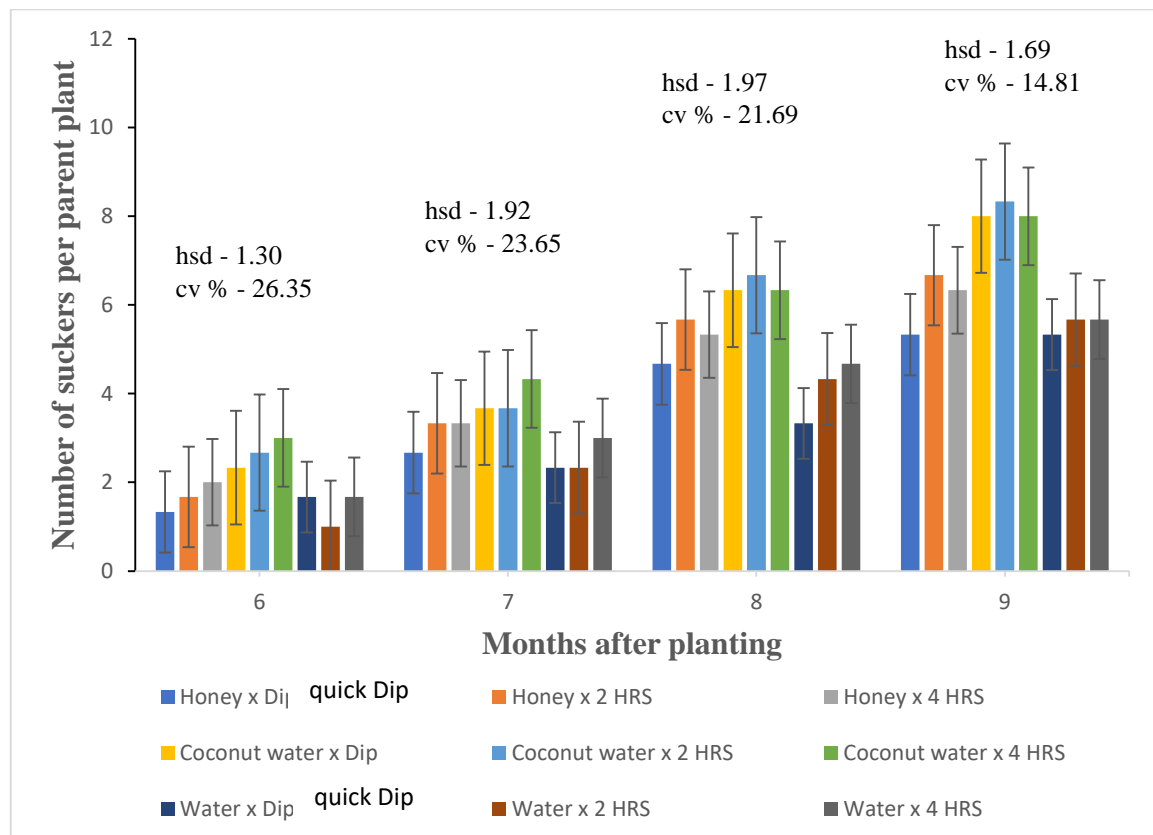


Figure 4.5b: Number of suckers per plant as influenced by the interaction of rooting hormones and dipping time

4.4 Yield and Yield Components

4.4.1 Number of suckers per plot and bunch weight per plot at harvest

Table 4.2 shows the effect of plant rooting hormones and water on number of suckers per plot at harvest. The results showed that coconut water was significantly ($P \leq 0.05$) different from the and ordinary water in number of suckers per plot at harvest. Dipping time was not significantly ($P \geq 0.05$) different among quick dip, 2-hour and 4-hour dip. The interaction between rooting hormones and dipping time was significantly ($P \leq 0.05$) different with coconut water plus all the dipping time producing significantly higher number of suckers at harvest than the water with quick dip, 2-hour dip and 4-hour dip which produced the same mean values.

From Table 4.2 the coconut water and honey both showed significant ($P \leq 0.05$) difference from water which produced the least bunch weight per plot at harvest (10.13kg). However, there were no significant ($P \geq 0.05$) differences between the dipping time in bunch weight per plot at harvest. There were significant ($p \leq 0.05$) differences between the interaction of coconut water with 4-hour dip from water with quick dip, 2-hour dip and 4-hour dipping in bunch weight per plot at harvest.

Table 4.2 Number of suckers per plot and bunch weight per plot at harvest as influenced by rooting hormones and dipping time

Rooting hormone	Number of suckers at harvest				Bunch weight per plot at harvest (kg)			
	Dipping time				Dipping time			
	Quick dip	2 hours	4 hours	Mean	Quick dip	2 hours	4 hours	Mean
Honey	6	7	7	7	13.37	12.30	12.73	12.80
Coconut water	8	8	8	8	14.37	13.53	16.77	14.89
Water	5	5	5	5	10.30	10.97	9.13	10.13
Mean	6.33	6.66	6.66		12.68	12.27	12.88	
CV (%)	16.66				16.98			
Rooting hormone (RH)	HSD (0.05) = 1.07				HSD (0.05) = 2.14			
Dipping time (DT)	HSD (0.05) = NS				HSD (0.05) = NS			
RH x DT	HSD (0.05) = 1.86				HSD (0.05) = 3.71			

CV = Coefficient of variation; HSD = Honestly significant difference at 5%

4.4.2 The number of fingers per bunch at harvest and bunch stalk diameter

Table 4.3 shows effect of rooting hormones and dipping time on number of fingers per bunch at harvest and bunch stalk diameter. A significant ($P \leq 0.05$) difference occurred in rooting hormones application to plantain with coconut water producing the highest number of fingers per bunch (35), followed by honey (31) and water with the least (27). There were no significant ($P \geq 0.05$) differences between quick dip, 2-hour and 4-hour dip in number of fingers per bunch at harvest. The coconut water with 2-hour dip produced significantly higher number of fingers per bunch at harvest than water with quick dip, 2-hour and 4-hour dip.

The dipping time showed no significant ($P \geq 0.05$) differences between treatment. However, the coconut water produced significantly the highest bunch stalk diameter (4.96 cm) than water (4.43 cm) in bunch stalk diameter. The interaction between the rooting hormones and the dipping time was not significantly different although the coconut water plus 4-hour dip showed superior performance in bunch stalk diameter.

Table 4.3 Number of fingers per bunch at harvest and bunch stalk diameter as influenced by rooting hormones and dipping time

Rooting hormone	Number of fingers per bunch at harvest				Bunch stalk diameter (cm)			
	Dipping time				Dipping time			
	Quick dip	2 hours	4 hours	Mean	Quick dip	2 hours	4 hours	Mean
Honey	31	29	32	31	4.33	4.67	4.60	4.53
Coconut water	33	38	33	35	4.93	4.90	5.03	4.96
Water	26	30	26	27	4.57	4.22	4.50	4.43
Mean	30.00	32.33	30.33		4.61	4.60	4.71	
CV (%)	12.08				10.68			
Rooting hormone (RH)	HSD (0.05) = 3.72				HSD (0.05) = 0.50			
Dipping time (DT)	HSD (0.05) = NS				HSD (0.05) = NS			
RH x DT	HSD (0.05) = 6.43				HSD (0.05) = NS			

CV = Coefficient of variation; HSD = Honestly significant difference at 5%

4.4.3 Bunch length at harvest and yield

Table 4.4 shows the effect of rooting hormones and dipping time on bunch length at harvest and yield of plantain. A significantly higher bunch length at harvest was produced by the coconut water (46.03 cm), followed by honey (44.16 cm) and water the least (40.50 cm) effect. There were however, no significant ($p \leq 0.05$) differences between the quick dip, 2-hour dip and 4-hour dip in bunch length at harvest. The interaction between the coconut water and 4-hour dip was significantly different ($p \leq 0.05$) from water plus 4-hour dip in bunch length at harvest.

Table 4.4 shows that the coconut water and honey gave a significant ($P \leq 0.05$) difference in performance from the ordinary water in yield. The performance of coconut water in yield was the highest (18.61 t/ha) followed by honey (16 t/ha) and least in the water (12.67 t/ha).

The time of dipping in table 4.4 showed no significant ($p \geq 0.05$) difference between treatments in yield. There were significant ($P \leq 0.05$) differences between the interaction of coconut water and 4-hour dip from water with 4-hour dip in yield.

Table 4.4 Bunch length at harvest and yield as influenced by rooting hormones and dipping time

Rooting hormones	Bunch length at harvest (cm)				Yield (t/ha)			
	Dipping time				Dipping time			
	Quick dip	2 hours	4 hours	Mean	Quick dip	2 hours	4 hours	Mean
Honey	43.00	47.57	41.90	44.16	16.71	15.38	15.92	16.00
Coconut water	45.83	45.87	46.40	46.03	17.96	16.92	20.96	18.61
Water	44.40	42.33	34.77	40.50	12.88	13.71	11.42	12.67
Mean	44.41	45.26	41.02		15.85	15.33	16.10	
CV (%)	10.55				18.90			
Rooting hormone (RH)	HSD (0.05) = 4.59				HSD (0.05) = 3.26			
Dipping time (DT)	HSD (0.05) = NS				HSD (0.05) = NS			
RH x DT	HSD (0.05) = 7.95				HSD (0.05) = 7.78			

CV = Coefficient of variation; HSD = Honestly significant difference at 5%

4.5 Correlation Matrix Analysis

Table 4.5 shows the correlation matrix between some growth, yield and yield components. Each cell in the matrix shows the correlation between two variables, indicating the strength and direction of their linear relationship. The correlation coefficient values and the associated significance levels for 0.83 *** between plant height and stem diameter suggests a very strong positive correlation, that taller plants tend to have larger stem diameters or whilst the plant height increases the stem diameter increases as well. In Table 4.5 the observed relationship of correlation coefficient of 0.27 ns between plant height and bunch

length at harvest shows no significant correlation. There are weak, positive correlation and statistically not significant linear relationship between plant height and bunch length.

The correlation coefficient value 0.02 ns between number of leaves per plant and number of suckers at harvest suggests a very weak, non-significant relationship at $P > 0.05$ hence in practice there is no linear relationship between number of leaves per plant and the number of suckers. The correlation coefficient of 0.71** between bunch length at harvest and bunch yield (t/ha) shows a strong and highly significant positive correlation, suggesting that longer bunches are strongly associated with higher yields. Table 4.5 shows a positive correlation when there was increased in bunch length which led to increase in bunch yield, therefore there is a linear relationship between the bunch length and bunch yield at harvest at coefficient value of 0.71** at $P \leq 0.01$ indicating a very strong statistical relationship. Moreover, Table 4.5 shows a linear relationship between number of fingers per bunch at harvest and the bunch yield with coefficient value of 0.62** at $P \leq 0.01$ suggesting a strong statistical relationship.

Table 4.5 Correlation matrix among growth, yield and yield parameters of plantain as influenced by rooting hormones and dipping time

	1	2	3	4	5	6	7	8
1. Plant height	1	0.83***	0.75***	0.26ns	0.33ns	0.43*	0.27ns	0.48ns
2. Stem diameter		1	0.72***	0.13ns	0.43*	0.36ns	0.37*	0.46*
3. Number of leaves per plant			1	0.02ns	0.10ns	0.26ns	0.16ns	0.29ns
4. Number of suckers at harvest				1	0.32ns	0.48**	0.37ns	0.53**
5. Bunch stalk diameter at harvest					1	0.21ns	0.58*	0.60***
6. Number of fingers per bunch at harvest						1	0.40*	0.62***
7. Bunch length at harvest							1	0.71***
8. Bunch yield (t/ha)								1

*Numbers against the parameters in columns correspond with variables in rows; NS – Not significant at $P > 0.05$; * = Significant at $P \leq 0.05$; ** = Significant at $P \leq 0.01$; *** = Significant at $P \leq 0.001$*

CHAPTER FIVE: DISCUSSION

5.1 Phenology of Plantain as Affected by Coconut Water, Honey, Water and Dipping Time

The performance of the mother plant in terms of growth and development leading to good yield involves processes such as differentiation, plant growth regulations, photoperiodism and other physiological factors and consequently a good yield. A successful vegetative growth phase under a required environmental condition and management practices will enhance the reproductive growth phase for better yield.

From Table 4.1 water as a control recorded the highest mean value for fruiting and consequently affected the maturity period over the coconut water and honey, which indicates days to 50% to fruiting and maturity of treated plantain plantlets with coconut water and honey significantly shortened the number of days to fruiting and maturity.

The indication is that the phytohormones in the coconut water and honey might increase nutrient uptake due to the correlation between the root growth mobilization factors and the photosynthetic activities. A well-established rooting system ensures rapid absorption and transport of available minerals through the xylem to enhance photosynthesis and all the assimilate will be channeled to fruit formation and maturity with reduced number of days.

Paul and Singh (2021) confirmed the effect of using plant extracts for rooting of *Vitex diversifolia* during horticulture cuttings. Four treatments selected were (Indole Butyric Acid (IBA), Aloe Vera, Coconut Water and combination of Aloe Vera + Coconut Water. He found that treatment with Aloe Vera, Coconut Water and combination of Aloe Vera + Coconut Water had more root length (15, 15, 17 mm respectively) than IBA (8 mm). It has been revealed that a well-established rooting system is an anchor of the plant and enables

rapid water and mineral absorption which ensures early inflorescence and speed maturation which consequently influence the yield and yield components().

(Abdel-Rahman *et al.*, 2020), Naphthalene acetic acid (NAA) is a plant hormone in the auxin family that plays an important role in fruit formation, abscission, cell elongation, apical dominance, photoperiodism, and geotropism. Wagle *et al.* (2022) research work revealed that application of paclobutrazol induce early and profuse flowering, increase fruit set reduce fruit drop and high yield in mango plant.

Varying dipping time however, showed no significant differences ($P \geq 0.05$) among the quick dip, 2- hours dip and 4- hours dip for days to 50% days to fruiting as showed in Table 4.1. Different plant hormones respond differently to rooting hormones and dipping time. A rooting hormone that works for one plant might not be effective or even detrimental to another plant. Therefore, experimentation and plant-specific recommendations are crucial factor for the application of rooting hormones and related dipping time (www.researchgate.net).

5.2 Vegetative Growth of Plantain as Affected by Coconut Water, Honey, Water and Dipping Time

The height of suckers and their respective number of suckers around the parent plants also recorded significant difference in performance with the influence of the plant hormones; coconut water and the honey as against water. Similar results have been achieved by several researchers on the uses of organic hormones on vegetative propagules because of sufficient concentration of the presence of phytohormones; cytokinin and auxin for roots induction and shoot growth as confirmed by Paul and Singh (2021) studied the effect of natural substances in comparison to synthetic hormone in grapevine cutting in horticultural work.

It was established that Aloe vera gel treatment resulted in longest root length (12.9 cm) followed by IBA (10.9 cm) whereas the smallest root length (5.2 cm) was measured in the control treatment. He concluded that aloe vera gel is the best natural substance which can be a potential alternative rooting hormone to synthetic rooting hormone for propagation of grapevine. Aloe vera leaf extract is confirmed to have phytohormones and nutrients like GA3 16 mg/100gm fresh weight, IAA 0.6 mg/100 gm fresh weight, ABA 3.1 mg/100gm fresh weight, Glucose 3 g/100g, Protein 1.0 mg/g and other biological active ingredients.

However, in most of the vegetative parameters; between coconut water and honey; the analysis revealed that coconut water performed better than the honey; such as the number of suckers sprouted around parent plants; which also aid in stabilizing the mother plants besides being the next generation of ratoon to the mother plant. This current research is similar to Bogale (2018) who used biotechnological approaches of micro and macro technique of raising suckers as the best option to overcome constraints and improve the quality of planting materials and productivity. These practices provide a means of rapid production of large quantities of healthy and identical propagules for large scale production of plantain plantlets. Cultivation within a short period and limited space without seasonal dependency in contrast to conventional propagation.

The increase in parent plant height could be due to the sharp significant difference between the natural hormones, coconut water and honey over the ordinary water. The slight increase in the average height of plantlets exhibited by the treatments most especially coconut water followed by honey in that trend could be attributed to the traces of growth regulators responsible for stem elongation due to better rooting system and mineral uptake. It has been revealed by Abdel-Rahman *et al.*(2020) that seaweed extract was used to stimulate root formation on cuttings of *Araucaria heterophylla* due to the fact that it contains plant growth

regulators such as cytokinin and auxins such as IAA, betanine and IBA as well as amino acids, vitamins, enzymes, sugars, antioxidants and nutrients similar to that of coconut water which trigger the release of phytohormones to induce the endogenous structures for rooting.

Figure 4.3a there was no significant difference among the treatments in mean number of leaves per plant, although coconut water emerged the highest in leaf number across the cropping period except at the 8th month after planting, followed by honey and ordinary water from the 6th to 8th month after planting. Moreover, there was a general trend of gradual increase in mean number of leaves per plant for the various dipping time. There was no significant difference in the interaction of rooting hormones and dipping time. Karunarathna *et al.*, (2019a) research revealed that coconut water also contains higher quantities of auxins and cytokinin and may be the reason for higher number of leaves in *Sanchezia* spp. stem cuttings observed as compared to other treatments like ordinary water, bee honey and moringa extract.

Merwad (2018) reported that spraying with moringa leaf extract (MLE) as a natural plant hormone on some selected crops such as tomatoes, maize and common beans increased growth characteristics measured; number of leaves, leaf area, number of tillers and plant height. These were attributed to the accumulation of calcium (Ca), vitamin C, potassium (K), nitrogen (N) and crude protein which are useful for the formation of protoplasm, whilst growth hormones enhance rapid cell division, cell multiplication and enlargement. A similar report by Abdel-Rahman *et al.* (2020) on rooting behaviour in stem propagation by application of coconut water and similarly honey after successful sprouting has also been done.

There is a correlation in a proportionate increase in leaves concerning well established rooting system which enhances leaf initiation by phyllotaxis contained in the apical meristem coordinated by auxin and it determined the initiation of leaflets and lodes from the margin of the leaf primordia which affect the number of leaf formation. The significant increase in mean stem girth of plant from the 6th to the 7th months after planting might be accounted for, by the efficient function of the roots and other growth and development processes; such as photosynthesis, assimilate transport, cell division and other abiotic cues might have enhanced the mean stem girth. The stem girth of the parent plants which saw most often recording the highest mean girth was coconut water, might have influenced the cell division, assimilate transport that ensures girth enlargement to allow the stem to support heavy bunches formation during fruiting. Ekinici *et al.* (2018) established that the increased in stem girth of okro plant asserted by the presence of cytokinin present in moringa leaf extract which promoted the cell division and cell elongation as stem girth of okro, recorded maximum girth of (4.12 cm) in the treatment of T1: Soil + Cocopeat + Moringa leaf extract followed by T2: Soil + Cocopeat + Chitosan of (3.85cm) which recorded minimum girth as the control of (2.40 cm).

There was proportionate increase in leaves with respect to well established rooting system, leaf initiation from the apical region was coordinated by auxin which has the antiseptic and antifungal properties which will help guard against bacterial and fungal problem (Yemataw *et al.*, 2018). Bogale (2018) studied the garlic extract on rooting of grapes cuttings. He observed the highest root length (19.67 cm) at a rate of 50 g/L garlic extract application than the least root length (12 cm) of control. He arrived to a conclusion that garlic extract is having

significant impact on rooting and root length of grapevine. The root cell callus formation is enhanced by the application of the appropriate rooting hormones to induce rapid sprouting (Opata *et al.*, 2021).

In general, the varying dipping time showed no significant differences ($P \geq 0.05$) as treatments between the quick dip, 2-hour dip and 4-hour dip in most of the vegetative parameters, such as plant height, number of leaves per plant and the interaction between coconut water with 4-hours dip showed significant responses from other vegetative parameters such as the number of suckers per plant and plant height.

Similar research work by Abdel- Rahman *et al.* (2020) reported that treating cuttings with coconut water for 1 hour was better than coconut water for 3 minutes. The dipping duration of cuttings in coconut water of *Bougainvillea spectabilis* and *Bougainvillea glabra* cuttings significantly affected the rooting ability. The best rooting performance was obtained from *B. spectabilis* and *B. glabra* cuttings dipped in coconut water for 1 hour, while *B. spectabilis* *B. glabra* cuttings had no roots when dip in 3 minutes.

Bogale (2018) also reported that, using different concentration of solution (sodium hypochlorite) with different exposure time significantly affected the impact of the two media differently. Murashige and Skoog (MS) media supplemented with different types and concentrations of auxins and cytokinins were used for culture initiation, shoot multiplication and root induction experiments and the result were - A maximum average number of shoots (8.53/corm and 5.8/sprout explants) were obtained on MS+8 mg/L BAP and 3 mg/L Indole-3-acetic acid (IAA). The highest mean root number (6.9) and root length (11.25 cm) per plantlet were recorded on half strength MS media supplemented with 0.5

mg/L IAA and 1.5 mg/L IAA, respectively. There is a correlation between rooting hormone concentration and time of dipping; higher concentration often requires shorter dipping time to avoid damaging the plant tissues while lower concentration require longer soaking periods to achieve the same effect (www.researchgate.net).

5.3 Effect of rooting hormones (Coconut water, Honey and Water) and dipping time on Plantain yield and yield components

The coconut water and honey as rooting hormones showed significant difference in bunch weight at harvest over ordinary water. There might be a correlation between efficient response of the vegetative parameters as against performance of plant during the reproductive phase and effect of rooting hormones. Research has shown that Plant Growth Regulators (PGRs) trigger the production of plant hormone which help the plant to withstand unfavourable soil conditions (Okolle *et al.*, 2020).

Application of growth hormones might have helped in stimulating plant growth; through rapid nutrient uptake as explained by Chanclud and Morel (2016) that mycorrhizal hypha root naturally favors better nutrient uptake. Coconut water application enhanced root formation, sprouting of axillary bud and shoot proliferation. According to Karunarathna *et al.* (2019b) the formation of adventitious root may trigger hormonal effect, typically Indole Acetic acid (IAA); the most abundant natural auxin, a weak organic acid that control a plethora of plant development including adventitious root formation as established in different species have correlation in fruit weight.

The significant response of the coconut water in terms of the number of fingers per bunch followed by the honey; although the rate of dipping showed no significant interaction could

be due to the effect of organic hormone on the reproductive phase of the plantain. A similar effect was observed by Wagle *et al.* (2022) when they studied the effect of naphthalene acetic acid (NAA), Gibberellic acid (GA), Sulphate of Potash (SOP) and the control on a bunch of characters of banana. Increased finger length and finger girth and other finger parameters due to 2,4-D application can be attributed to its impact on cell development and cell division and mobilization of photosynthetic assimilates to the developing fruits (Abdel-Rahman *et al.*, 2020). A role of PGRs in increasing fruit size and weight is caused by increasing both the cell division and cell elongation.

In many cases, these factors together affect fruit size. There are two factors affecting cell elongation, one increase in cell wall elasticity that probably is stimulated by auxins and the other is an increase in cell potassium content needed as an osmoticum for water absorption. Application of 2,4-D increases the fruit size which might be due to increasing carbohydrate absorption, cell development and elongation. Probably, auxin treatments by increasing cell wall elasticity can enhance the cell elongation and development (Guleria *et al.*, 2021).

The coconut water showing a sharp significant difference in bunch weight per plot from ordinary water could be attributed to the composition and effects of hormones. Research has shown that PGPR trigger the production of plant hormone which help the plant to withstand unfavorable soil condition (Opata *et al.*, 2021b). Application of growth hormones might have helped in stimulating plant growth; through rapid nutrient uptake as explained by Manju and Puspallata (2022), that mycorrhizal hypha root naturally favours better nutrient uptake. Coconut water application enhanced root formation, sprouting of axillary bud and shoot proliferation. According to Tetteh *et al.* (2019), the formation of adventitious root may trigger hormonal effect, typically Indole Acetic acid (IAA); the most

abundant natural auxin, a weak organic acid that control a plethora of plant development including adventitious root formation as established in different species have correlation in fruit weight.

The longest bunch length at harvest was produced by the coconut water, followed by the honey and water the least effect at harvest. The coconut water enhanced root development which can lead to better nutrients and water uptake, by releasing growth promoting substances for robust rooting system, plant establishment and survival and consequently higher potential bunch length.

Wagle (2022) research work confirmed that application of Gibberellic acid (GA₃) sprayed twice with standard operating procedure (SOP) of (1.5%) and through exogenous application might have kept the protein synthesis in an active state, allowing the fruit to continue and grow for a significant increase in the average weight and length of bunch.

A strong root system produced by rooting hormones can also improve plants tolerance to environmental stresses by promoting weather resistance which contribute to resilience of plant anatomy to convert the available soil nutrient into higher yield mass and quality fruit sizes.

Opata *et al.* (2021) work revealed similar findings where, treatments with water extracts of neem leaf, wood ash, mixture of the two extracts and a control without any extract were applied on Plantain suckers and planted at a spacing 2 m x 2 m and five plants of sprouted plantain suckers were randomly selected from each treatment plot for data collection on growth, yield and soil chemical composition. The results showed that there were significant increases in plantain growth, yield parameters and soil chemical composition under different treatments. The mixtures of neem and wood ash extracts increased significantly

the proliferation of root formation and axillary buds, lateral shoots and root callusing which translated into yield and yield components such as long and heavier fingers on an individual hands which correspond to bunch length compared to the controlled treatment.

The higher fruit yield in coconut water and honey than the ordinary water could be due to the fact that the application of the rooting hormones enhanced the propagation of the plantain corms which grew into more matured plants with well-established root system, that led to increased nutrient absorption and high yield. The highest yield in coconut water with 4-hour dip might be due to the effect of the coconut water and the optimal dipping time. This might have enhanced more roots formation that resulted in more established and healthy plant with higher yield than the other rooting hormones with short dipping time. The ideal dipping time depending on the rooting hormone type, its concentration and whether a quick dip or long dip method is used.

Correlation matrix analysis employed for specific practices such as interconnected aspects of plantain growth and ultimately, higher and quality yield, using statistical correlation analysis tool to uncover these relationships for future performance. This could be identified by providing insights into findings and established highly positive correlation of already research work to serve as a guide toward optimal propagation and cultivation practices for plantain.

Moreover, the varying dipping time of the rooting hormones interaction of coconut water with 4-hours dip, greatly influenced bunch weight at harvest compared to the rest of the dipping time. Interaction between the different dipping time and the rooting hormones showed coconut water plus 4-hours dip in superior performance in the number of fingers per bunch and bunch stalk diameter at harvest. Similarly, the bunch length at harvest was

also influenced by the 4-hours dipping time and coconut water interaction compared to the other varying dipping time and their respective rooting hormones. The related observation of interaction of coconut water plus 4-hours dip significantly influenced the performance in all phases of plantain production which goes to confirm the efficacy of the various phytohormones contain in coconut water when given ample time for the plant tissues to imbibe considerable concentration will stimulate the meristematic tissues to develop (Dzomeku., 2020).

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

From the findings of the research, the following are the major outlines on conclusion:

- Dipping of minisetts for 4 hours recorded the tallest mother plant height at 9 months.
- Minisetts dipped in coconut water for 4 hours recorded the earliest days to maturity, heaviest bunch weight per plot at harvest and widest bunch stalk diameter.
- Minisetts dipped in coconut water for 2 hours produced the highest number of fingers per bunch.
- There was a positive correlation between growth parameters and yield and yield components such as the number of fingers per bunch at harvest and the bunch length, the bunch stalk diameter and bunch yield.

6.2 Recommendations

The following recommendations are hereby made based on the results from the present study;

- Local farmers should be introduced to coconut water as a highly effective organic rooting hormone for enhancing the phenology, vegetative growth in plantain plantlets with significant impact on early fruit establishment and overall yield and yield components compared to honey or ordinary water.
- Farmers are encouraged to adopt the technology of using coconut water as rooting hormone by dipping plantain corm minisetts for 4-hour to enhance bunch weight, bunch length and fruit yield of plantain.

- Further research can be conducted to assess the combining effect of honey in a solution of coconut water as rooting hormone on growth parameter and yield components on plantain plantlets.
- Further research should be carried out on yield performance of first, second and third generation of ratoons in relation to the two organic hormones under regular field management.

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APPENDIX 1

WEATHER DATA DURING THE EXPERIMENTAL PERIOD, 2023

Month	Total Rainfall (Mm)	Relative Humidity (%)		Mean Temperature (^o C)	
		6: 00hrs	5: 00hrs	Min.	Max.
March	57.8	88	55	23.1	33.8
April	258.8	91	59	22.7	33.3
May	71.3	90	60	23.2	32.8
June	198.0	92	70	23.0	30.0
July	198.9	91	71	21.8	28.4
August	213.4	93	74	22.5	29.0
September	196.0	92	69	22.4	30.6
October	286.4	90	62	23.5	32.0
November	91.1	91	59	22.7	33. 1
TOTAL	1571.7				

(Ghana Meteorological Agency, 2023)