BINDURA UNIVERSITY OF SCIENCE EDUCATION

CROP SCIENCE DEPARTMENT

EFFECTS OF USING DIFFERENT ROOTING MEDIA AND INDOLE BUTYRIC ACID (IBA) TREATMENT, ON ROOT DEVELOPMENT AND SPROUTING OF HYBRID TEA ROSES (*ROSA X HYBRIDA*).

QUINTON J CHAUKE

B202492B

A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS OF THE BACHELOR OF AGRICULTURAL SCIENCES HONOURS DEGREE IN CROP SCIENCE

(CROP SCIENCE)

Date: November 2024

DECLARATION

I, Quinton James Chauke, do hereby declare that this dissertation is my original work and has not been submitted before for any academic award, either in this or other institutions of higher learning, for academic publication or other purpose. The references used in this research from other journals or materials are all indicated in the references section.

Signed…………..

Date…………….

Supervisor; Professor R. Mandumbu.

DEDICATION

I dedicate this project to my family and friends, who firmly provided much needed support and consolation throughout its duration. Their persistence in believing in the potential and abilities that I have, had a great impact on building alacrity in me, leading to my ultimate success. I also extend my dedication to my project supervisor, Professor R. Mandumbu, who offered indispensable guidance and tutoring me throughout the entire research process, topic construction to the finalization of my dissertation. He played a pivotal role in shaping my project and ensure its quality through his proficiency, patience and dedication.

ACKNOWLEDGEMENTS

Expression of my unfeigned gratefulness goes to the following individuals who significantly dedicated their important time pushing towards the success of this project. To start with, appreciating my family's crucial support, both financially and also their encouragement. I am also thankful to the Luxaflor Roses (Pvt) Limited company, particularly Mr. Mathias (the company's operations manager), Mr. T Changwa (the company's human resources manager) and also Mr. C. Semu (the company's propagation department manager). They provided me with the necessary resources and materials that enabled me to undertake this project. My heartfelt gratitude also goes to Professor Mandumbu, who offered important guidance and mentorship in molding my project from its commencement up to its completion. I am deeply grateful to him for showing much effort, patience and tolerance in addressing my numerous mistakes and queries. Furthermore, I would also like to acknowledge my closest friends' contributions through offering assistance and support at different stages of this project, from discussing ideas, field work up to providing feedback on my writing. This also enhanced the overall quality of my work. Last but not least, I would also like to express my gratitude to God Almighty for gratuitously impart the gift of life, knowledge and wisdom to me and my helpers, that enabled me to do and complete this work.

ABSTRACT

The most important factor that plays a pivotal role in the rooting and quality production of floricultural crops is the rooting media. In rose production, application of auxin-based, commercially available rooting hormones to the rooting media, is well-known for enhancing the process of regeneration of roots in the cuttings and their survival. In Zimbabwe, the commonly used rooting media in the production of hybrid tea roses, is a composition of coco-peat, vermiculite, calcium nitrate and the rooting hormone, Indole Butyric Acid. All these components are sold by suppliers at different prizes depending on quantity therefore using it can be costly. Small scale farmers are finding it difficult to venture into the production of the highly demanded hybrid tea roses by foreign markets, because of too much funds needed for inputs such as greenhouse facilities and media components. There is pressing need to analyze the use of freely available media and their effect on initiating root development and sprouting of hybrid tea roses so that costs of production can be minimized. This research aims to address this knowledge gap by examining the effect of applying the rooting hormone (Indole Butyric Acid (IBA)) in different rooting media, in enhancing root regeneration of grafted rose seedlings. An experiment was carried out in a greenhouse with controlled environmental conditions, where three different media were compared on initiating root regeneration and sprouting of three different hybrid tea rose varieties. Replicas of each of the three different media were prepared and no Indole Butyric Acid (rooting hormone) was added. Eighteen float trays were used to accommodate eighteen treatments, each treatment comprising of twelve grafted plants. Mature rootstalks (15 weeks old) from the Natal briar plant were used in the grafting process. The primary objective of this study was to assess root and shoot development of three Hybrid Tea rose varieties in three different rooting media with and without application of Indole 3-butyric acid. The data was analyzed using statistical tests (GenStat 7th edition) to determine whether the application of IBA in different media have a significant effect on the rooting and sprouting of different rose varieties. Indole Butyric acid proved to be a necessity depending on the rooting media in use. Its significant effect in promoting root and shoot development was seen in Vermiculite + coco-peat + Calcium nitrate media and in anthill clay media. Humus proved to be a good rooting media even without Indole butyric acid applied. The potential limitation of this research is that it will be conducted in a greenhouse with controlled environment therefore, the results may not be useful to other growing environments for roses.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

1.1 Introduction and Background

Hybrid tea rose (Rosa X hybrida) was developed by plant breeders in trying to enhance the quality of roses. They aimed at producing varieties that have the important rose traits such as large buds, longer and stronger stems, multi-colored buds, and longer vase life as well as, disease resistance. These are considered important traits especially hybrid tea roses for international market (Bundela & Fatmi, 2024). Since a long time ago, roses have been used world-wide, gracing homes and gardens as ornamental plants (Burch et al, 2019). Roses have a long and well-documented tradition in selection and breeding. They also hold the largest economic value of all the ornamental plants, being used as cut flowers, garden plants, and pot plants as well as industrial (perfume), medicinal and culinary applications (Leus et al, 2018). Introduction of greenhouse technology for cultivation of hybrid tea rose in the recent past years, has changed the scenario of its production in the world leading to a fierce competition on the international flower market (Kumar et al, 2012 and Makwana et al, 2015). Many countries such as India and China, generates high amounts of revenue through rose exports. By 2019, Zimbabwe was one of the African top exporters of roses, amongst Kenya, Uganda, Ethiopia, Tanzania and Zambia (Bhagat et al, 2019). In Zimbabwe, besides generating income, rose production has been providing employment opportunities to local people, for example, about 3000 people were employed at Luxaflor Roses (the main producer of roses in the country) by 2021 as confirmed by Roelof Nugteren, the company's general manager, in May 2021.

According to Rossa et al (2019), cultivation of plants such as roses in commercial nurseries can be difficult due to the lack of knowledge regarding reproductive phenology and propagation techniques that provide higher productivity and profitability for horticulturists. In Zimbabwe, large scale commercial rose farms such as Luxaflor Roses (pvt) Ltd, are also facing high production costs. These costs include the input costs of purchasing rooting media components such as rooting hormones (IBA), vermiculite, coco-peat and synthetic fertilizer, calcium nitrate. Indole Butyric Acid (liquid, gel or powder) price ranges from USD $30 to $70 per 10 grams, at companies such as Plant Cell Technology (USA), Lab Craft Technologies and Ubuy India. It is not produced locally in Zimbabwe. Vermiculite price ranges from $400 to $500 per ton. Coco-peat price ranges from USD $8 to $10 per 5kg block. Calcium nitrate price ranges from USD $15 to $20 per 20kg at companies such as Zimbabwe Fertilizer Company and Windmill. According to Sueitt et al (2015), exposure of a synthetic fertilizer, calcium nitrate, to fresh water decreases the density of Cyanophyceae members and other benthic taxa. In response, this research aims to explore the potential of recycled humus from rose residues and naturally occurring clay soil, as an environmentally friendly, sustainable and a cost-effective way in the production of hybrid tea rose. This research investigates the practicality of applying rooting hormone, IBA, in rose humus medium, clay soil medium and the commercially supplied medium of coco-peat mixed with vermiculite and calcium nitrate. Time taken for root regeneration and sprouting of grafted hybrid tea rose will be used to analyze this.

In previous studies, it has been mentioned that rooting hormones such as IBA, can be used to increase rooting capacity of different varieties in a positive way and even to obtain a higher number of rooted cuttings in a shorter period of time (Kentelky. E, 2023). The most essential characteristics of a good rooting/growing media for roses are, good porosity, light weight, optimum drainage, slightly acidic with optimum Cation exchange capacity (CEC) and pathogen-free (Kumarashinghe H. et al,. 2016). Coco-peat, vermiculite and calcium nitrate are mixed so as to complement each other and meet the above characteristics. This research was aiming to see if clay soil and rose humus alone, can promote root and shoot regeneration since they meet some of the above characteristics such as good drainage, good CEC, and slightly acidic.

1.3 Problem statement

Rose producers in Zimbabwe are experiencing high costs of production mostly during propagation of roses, with rooting media inputs consuming more funds from purchasing to media preparation, since the input costs are usually variable. Rose producers end up experiencing diminishing marginal returns and decreasing returns to scale. According to Heri (2000), quality of technical advice and growing techniques is one of the factors affecting the viability of horticultural exports in Zimbabwe. The purpose of this research is to evaluate the use of naturally occurring rooting media (clay and rose humus), and coco-peat and vermiculite media, evaluating the effects of rooting hormone (IBA) application in those rooting media. The findings may be used by rose producers and may also lure and encourage small holder famers to grow roses incurring lower costs of production since the media without IBA have the potential to perform as good as those treated with rooting hormones.

1.4 Justification

The goal of this research is to come up with the best rooting media for roses, which is also cost-effective, sustainable and productive. This will contribute to the nation's exports revenue since roses can be sold on international markets. It will also provide knowledge to small scale farmers on the production of hybrid tea roses.

1.5 Aim

The primary aim of this research is to investigate the efficacy of applying Indole Butyric Acid in different rooting media (coco-peat, vermiculite and calcium nitrate media, clay soil media and rose humus media) to facilitate root and shoot regeneration of three different rose cultivars.

1.6 Specific objectives

- To determine the effects of decayed rose residues used as media, in promoting rooting and shooting of grafted hybrid roses.
- To determine the effects of using clay soil alone as media, in initiating root and shoot development on grafted hybrid roses.
- To determine the result of using coco-peat, vermiculite and calcium nitrate media, in the initiation of roots and shoots development of grafted hybrid tea roses.
- To evaluate the application of Indole Butyric acid in those media in enhancing faster root and shoot development of hybrid roses.

1.7 Hypothesis

- Indole butyric acid application will have a direct impact on the rooting and shooting of hybrid tea roses.
- Humus from rose residues will initiate root and shoot regeneration of grafted roses.
- A mixture of coco-peat, vermiculite and calcium nitrate, will initiate root and shoot development.
- Clay soil media will delay the process of root and shoot regeneration of grafted hybrid tea rose.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter intends to highlight the work that has already been done by other researchers, their perspectives and effective contributions in the comparison of different rooting media, effects of Indole Butyric Acid on the root and shoot regeneration of Hybrid tea roses.

2.2 Biology and Ecology of Hybrid Tea Rose

The rose (Rosa spp.) of Rosacaea family, is one of the most popular flowering plant species grown worldwide (Canci & Kilic, 2020), and is the most cultivated ornamental plant for commercial purposes. According to Jing et al (2011), three recognized double-petaled Rosa odorata (Andrews) Sweet (Rosoideae, Rosaceae) varieties, are the ancestors of modern hybrid tea roses that have a definite and permanent impact on the evolution of modern garden roses. These modern roses are a result of centuries of complex crosses involving the limited genepools of a number of mainly diploid species of the genus Rosa (Nybom, 2009). Hybrid tea flowers are well-formed with large, high-centered buds, supported by long, straight and upright stems. They have pointed buds that open slowly, and their flowers can grow 3 – 8 cm wide. There are thousands of rose varieties and hundreds of species. Hybrid tea rose can be grown on open field or in greenhouses and it requires a pH range of 6 to 6.9. The essential minor elements have been indeed reported to play an important role in the proper growth and development of roses. Minerals such as Calcium, Iron, Potassium, Manganese, Sodium, Phosphorus, Nitrogen and Zinc, have a great contribution to rose growth (Shohayeb et al, 2015). During propagation, warm and humid conditions should be maintained to avoid wilting of seedlings.

According to Dogan et al (2020), hybrid tea roses are well-known for their difficult sexual reproduction, therefore, they are usually propagated through cuttings and grafting. Rose production increases yearly although, propagation methods are the chief challenge in producing it (Guaita-pradas et al, 2023). Hybrid tea roses are produced through vegetative means (cuttings and grafting methods) to maintain their desirable genetic characteristics. Genotypic differences among hybrid tea rose cultivars can influence adventitious root formation during different propagation methods (Nguyen et al, 2020). Type of media used and application of a certain type of rooting hormone can also influence the rose's rooting and shooting system success during propagation. After comparing different rose varieties grafted on three different rootstalks, Kwon et al (2022) concluded that the effectiveness of grafting depends on the type of the scion and rootstock. *Rosa multiflora* (Natal Briar) rootstocks had the outstanding performance because of its desirable traits such as high rooting, the possibility of faster regeneration after cutting, the ability to adapt to different culture media and high resistance to root diseases (Shaafi et al, 2022).

Cut roses are mostly preferred among roses grown for decorative purposes. This is evidenced by millions of cut roses of different colors, shapes, and types, being produced in more than 50 countries yearly (Trademap, 2022).

2.3 Characteristics of the rooting hormone, IBA.

Indole-3-butyric acid (IBA) is a kind of auxin (plant growth hormone) that exists naturally in various species of plants and tissues, and is well-known primarily for its ability to enhance cell expansion, root initiation, vascular tissue differentiation, bud and flower growth (Davies, 2013).

Khadr et al (2020), stated that, in several bioassays, IBA has auxin activity and affects the rooting process in various plant species more obviously than Indole 3-acetic acid. Mohammed et al (2024), stated that several studies have been run to test different auxins for promoting adventitious roots in the rose cuttings, notably by applying IBA, which is more stable than other auxins. Optimum IBA concentration have a positive impact on root regeneration on Natal Briar cuttings (Pourghorban, 2020).

2.4 Rooting media in hybrid tea production

According to Kumar et al (2019), the production of floricultural crops involves a number of cultural inputs and among them, the most important factor which plays a major role in quality production and rooting of herbaceous cuttings of plants is rooting media. Rooting media/ propagation media, also known as the substrate, serves as the growing medium that provides essential support, aeration, water retention and nutrients to promote root and shoot development and growth in cuttings. A good rooting substance must be easily available, economically attractive, ecologically sound mean of reducing external inputs, for example, humic acid, vermin wash, aloe vera, and honey (Rajan & Singh, 2021). Usually rose cuttings are grown in containers with a shallow depth, therefore, rooting media must be amended to provide the appropriate physical and chemical properties necessary for plant growth (Kumar et al, 2019). In some rooting media for hybrid tea rose, Calcium nitrate is usually added to promote elongation and division of plant cells, cell membrane permeability, nitrogen metabolism and translocation of carbohydrate (Akladious & Mohamed, 2018). Below are some of the rooting media that can be used to promote root and shoot development of hybrid tea rose;

2.4.1 Vermiculite

Vermiculite is considered one of the most investigated clay materials from a structural viewpoint. In the family of naturally occurring 2:1 aluminosilicate clay minerals, vermiculite (phyllosilicate) is a very important member (Wang et al, 2016). Although it has a similar sandwiched structure with other clay minerals (i.e., montmorillonite, illite, mica, sapolite, laponite), some of its structure features and properties are significantly different from those of clay minerals (Wang & Wang, 2019). For instance, vermiculite can be expanded to form expanded vermiculite when heated and expanded vermiculite has excellent thermal insulating properties and thermal stability. The 2:1 layer of vermiculite is composed of an MgO2(OH)4 octahedral sheet symmetrically coupled to an tetrahedral sheet of silica (Wang et al, 2016), and the hydrated exchangeable cations Mg2 +, Ca2 +, Na+ and K+ located in the interlayer space between the parallel 2:1 layers compensate its positive charge deficiency. The pH of vermiculite can range from 6 to above 9.5, depending on the source of the vermiculite. Vermiculite is a widely available, easily handled, odorless, and low-cost material. Vermiculite and modified vermiculite are commonly used in agricultural (as fertilizer carrier, adsorbent, etc.). In the propagation of hybrid tea rose, vermiculite is better because it have a high cation exchange capacity, good aeration and provides good root penetration, although, it have a poor water holding capacity hence requires regular water supply.

2.4.2 Coco-peat

According to Kumar et al (2019), cocopeat is a multipurpose growing medium made out of coconut husk after the fibrous husk is pre washed, machine dried, sieved and made free from sand and other contaminations such as animal and plant residue. He also stated that, cocopeat is considered as a good growing media component with acceptable pH (less acidic), electrical conductivity and other chemical attributes. In horticultural crops such as roses, it can facilitate root initiation and root length. Due to its ability to enhance aeration and water retention, cocopeat can be mixed with other rooting media for better results (Kumar et al, 2019).

2.4.2 Humus

In classical soil science, humus is the dark organic matter in soil that is formed by the decomposition of plant and animal matter (Popkin, 2021). It is a kind of soil organic matter. It is rich in nutrients and retains moisture in the soil. In agriculture, humus also refers to a mature or natural compost extracted from a woodland or other spontaneous source for use as a soil conditioner. The ratio of carbon to nitrogen (C: N) of humus commonly ranges between 8:1 and 15:1 making it able to improve soil health (Cotrufo et al, 2022). Humus is amorphous and lacks the cellular structure characteristic of organisms, but, it also significantly improves (decreases) the bulk density of soil (Voltr et al, 2021). It have a good moisture retention properties. Effective humus and stable humus are additional sources of nutrients for microbes. The former provides a readily available supply, and the latter acts as a long-term storage reservoir. Stable humus can the best for propagation of herbaceous plants since it provides immediate impacts that are needed for plant growth.

2.4.3 Clay soil

Clay is a type of fine-grained natural soil material containing clay minerals (hydrous aluminium phyllosilicates, e.g. kaolinite) (William, 2000). Most pure clay minerals are white or light-colored, but natural clays show a variety of colors from impurities, such as a reddish or brownish color from small amounts of iron oxide. The particle size of clay minerals is less than 2 microns which can be present in form of plastic in the presence of water and solid when dry (Kumari & Mohan, 2021). The main groups of clays include kaolinite, montmorillonite-smectite, and illite, and also vermiculite is sometimes classified as a clay mineral (Kumari & Mohan, 2021). Clays have a high Cation exchange capacity, making them good in retaining nutrients. Their closely packed particles means they are extremely efficient in water retention. Anthill clay, which was used, is a distinct soil/clay genre among common soil types because of the extraordinary stockpiling method (Aluvihara et al, 2020). The small particles are carried in and erected an anthill by a termites (of insect order, Isoptera). Anthill soils can play a crucial role as an alternative to chemical fertilizer for farmers who have no means of buying inorganics. Because of this, we assume that it can be useful if used as media in rose propagation.

Conclusively, the growing media should have various favorable characters such as light-weight, good porosity, well-drained but with optimum water holding capacity, slightly acidic with optimum cation-exchange-capacity, constant volume when wet or dry, lack of insects, diseases and weed seeds, low content of silt, clay and ash, easy storage for long periods of time without changes in physical and chemical properties, and easy handling and blending.

CHAPTER 3: METHODOLOGY

3.1 Description of the site of experiment

The study was conducted at Luxaflor Roses farm at Manyewe North Farm in Concession, Zimbabwe. Concession is a small town in Mashonaland Central province in Zimbabwe, which is located approximately 45 km from Harare and is along Mazowe to Mvurwi road. Luxaflor Roses (Pvt) LTD is about 7km west of Concession town. It is located in Natural farming region II and is located at -17.40566° S latitude and 30.87789° E longitude. The area receives about 700 mm to just over 1000 mm of average rainfall annually. At Luxaflor Roses, hybrid tea roses are grown under controlled environment, plastic greenhouses, which can boost their performance. The propagation greenhouse that was used for the experiment is equipped with temperature and humidity control systems, and irrigation systems. Internet of Things (IoT) system is used for automatic management of the inside environment to suit the required conditions. It facilitates opening and closing of the vents and the supply of water through misting following the set parameters of temperature, humidity and irrigation intervals. Thermometers and hygrometers are used to record temperature and humidity. This propagation greenhouse is designed to facilitate root and shoot development and grafted plants are transferred to the hardening house after they have successfully completed root and shoot regeneration process.

3.2 Experimental design

The study employed a 2 x 3 x 3 factorial experiment that was laid down as a Random complete block design to ensure full experimental control and minimize bias. Three factors were being tested for, which are, rooting hormone (IBA) effect, performance of three different varieties and performance of three different rooting media. Eighteen treatments were created, each block having a different treatment. Float trays were used and each float tray represented a block with its own treatment, because a single float tray can accommodate 36 plants. Each float tray had 20 grafted rose plants. The 18 treatment combinations are shown in table 3.1 below;

Table 3.1 Treatment description

T. symbols	Description
$T_1M_1H_1V_1$	Whatever variety in Vermiculite, coco-peat and calcium nitrate media with rooting hormone (IBA).
$T_2M_1H_1V_2$	Harmony variety in Vermiculite, coco-peat and calcium nitrate media with rooting hormone (IBA).
$T_3M_1H_1V_3$	Kariba variety in Vermiculite, coco-peat and calcium nitrate media with rooting hormone (IBA).
$T_4M_1H_0V_1$	Whatever variety in Vermiculite, coco-peat and calcium nitrate media without rooting hormone (IBA).
$T_5M_1H_0V_2$	Harmony variety in Vermiculite, coco-peat and calcium nitrate media without rooting hormone (IBA).
$T_6M_1H_0V_3$	Kariba variety in Vermiculite, coco-peat and calcium nitrate media without rooting hormone (IBA).
$T_7M_2H_1V_1$	Whatever variety in Humus media with rooting hormone.

$T_8M_2H_1V_2$	Harmony variety in Humus media with rooting hormone.
$T_9M_2H_1V_3$	Kariba variety in Humus media with rooting hormone.
$T_{10}M_2H_0V_1$	Whatever variety in Humus media without rooting hormone.
$T_{11}M_2H_0V_2$	Harmony variety in Humus media without rooting hormone.
$T_{12}M_2H_0V_3$	Kariba variety in Humus media without rooting hormone.
$T_{13}M_3H_1V_1$	Whatever variety in Clay soil media with rooting hormone.
$T_{14}M_3H_1V_2$	Harmony variety in Clay soil media with rooting hormone.
$T_{15}M_3H_1V_3$	Kariba variety in Clay soil media with rooting hormone.
$T_{16}M_3H_0V_1$	Whatever variety in Clay soil media without rooting hormone.
$T_{17}M_3H_0V_2$	Harmony variety in Clay soil media without rooting hormone.
$T_{18}M_3H_0V_3$	Kariba variety in Clay soil media without rooting hormone.

T – Treatment

V – Variety type

M – Rooting media

H – Rooting hormone (Indole Butyric Acid)

M_1 - rooting media comprising of vermiculite, coco-peat and calcium nitrate.

M_2 – humus (rose compost) media.

M_3 – clay soil media.

H_1 – Rooting hormone present

H_0 – No rooting hormone

V_1 - Whatever

V_2 – Harmony

V_3 – Kariba

3.3 Agronomic practices

3.3.1 Rooting media preparation

Three different rooting media were prepared for use. The first rooting media was a mixture of three 5kg blocks of coco-peat, 50kg vermiculite and 10kg calcium nitrate. Water was added to ensure thorough mixing, supply optimum moisture needed to avoid wilting of the plant rooting section and also ensure that the media is well compacted to provide anchorage to the grafted rose plants. Clean water was used to ensure that no contamination by dangerous microorganisms takes place. The second rooting media that was used is humus obtained from decayed rose plant residues. Dark-colored humus taken from underneath the compost heaps was used because it was almost completely decomposed. The amount needed was determined by the number of float trays needed for humus treatments and in this case humus needed to cover six float trays was collected. No fertilizer supplements were applied in this medium. Water was added to supply optimum moisture needed for plant anchorage and prevent wilting of the rooting section. Lastly, the clay soil used was reddish, obtained from anthill and no fertilizer was added to it. Water was also added at the same time avoiding saturation of the clay with water as this can disturb aeration within the medium. The amount of clay used was determined by the number of float trays used for treatments with clay soil media.

3.3.2 Indole Butyric Acid solution preparation.

Indole-3-butyric acid solution of 98% efficiency, was prepared at the rate 100 parts/million. Clean water obtained from underground was used because it was free from contaminants. The solution was prepared and put in small bowls, a few minutes before use because, once prepared, it is not allowed to be kept for a long time before use.

3.3.3 Grafting of hybrid tea rose varieties

Natal Briar plants which were grown under thorough management for fourteen weeks, were used as rootstocks in the grafting of the three varieties used (*Rosa hybrida cv*. Whatever, *Rosa hybrida cv.* Harmony and *Rosa hybrida cv.* Kariba). They were well managed to ensure that they are disease and pest free, and they are strong enough to grow scion cultivars on them. Regularly sterilized secateurs were used to cut rootstocks from the field and cultivar scions from the greenhouses. During grafting, rootstalks were pruned all buds using sharp knives and cut to about 3 centimeters length with the top part cut at an angle (about 2 inches of sloping wood). The scions of the three cultivars were also pruned all buds and nodes leaving one leaf protecting the bud that will shoot into new plant. A rootstock and a scion of similar diameter were attached so that there is good lining of the bundle sheath. Silicone grafting tubes that varies in size, were used to tighten the joined part to make sure that it’s airtight and also doesn’t allow water to get to the joint to avoid rotting. However, a rootstock of about 3 centimeters and a scion of about 3 centimeters jointed by a silicone grafting tube, makes the full grafted planted that is ready for planting. 20 plants per each variety were grafted under shed to minimize wilting of the rootstalks, bud-wood (scions) and grafted plants. Water was also being applied in grafted plants leaves to avoid wilting.

3.3.4 Preparation of the planting site

Eighteen float trays were filled with rooting media. Each media type was filled in six float trays, that is, six trays had M_1, other six trays had M_2 and other six trays had M_3. A single float tray have 12 x 6 cells. To promote good plant spacing, only three rows of 12 cells were filled with media, leaving rows between them empty, therefore, each float tray can accommodate 36 rose plants instead of 72. Float trays were put on metal tables inside the propagation greenhouse. The tables were 1 and half meters above the ground so as to reduce the distance between irrigation water as it is applied in mist form.

3.3.5 Planting

Grafted rose plants that were to be treated with Indole butyric acid (all plants in treatments with H_1), were dipped in the solution for 5 minutes before planting so that the rootstock absorbs enough rooting hormone needed. Grafted plants were planted uniformly, with the single leaves left on each scion, facing the same direction. 20 plants of the same variety and treatment were planted in each tray. In other words, each tray had 20 plants and it represented a treatment. Planting was done in the propagation greenhouse. The propagation greenhouse is divided into four sections that differs in terms of water supply frequency. Frequency decreases with sections in ascending order. Grafted plants stays for only a week in each section to facilitate hardening as the plants undergo rooting and shooting processes. Trays with grafted plants were firstly placed in Section 1 for a week where there is high frequency of water supply

3.3.6 Crop management

Regular monitoring was done (after every two days) to check for the presence of weeds and pests especially in clay and humus media which were not checked for those factors during media preparation. It was also done to check for any disease development on the plants since diseases such as Downey mildew can develop in humid conditions. Dead plants were being removed from the trays and thrown away. The experiment was carried in October when solar radiation was high (32 ^{0}C average) therefore, the irrigation water was being automatically supplied sixteen times (average) a day at 2.5 bars water pressure, with each irrigation time lasting for 20 seconds. The computer system could also automatically open vents during the day when temperatures rose to higher levels (31 to 33 degrees Celsius). The plants were carefully transferred from section to section weekly.

3.4 Data collection procedure

3.4.1 Measuring root development

Under normal circumstances, hybrid tea roses grown in a highly efficient media with efficient rooting hormones, are expected to start showing signs of root development after 6 – 7 days. However, root development was firstly assessed after a week, by taking samples of healthy plants from each treatment. This was done regularly (after every two days) so as to observe changes in time. Visual inspections were done at early root regeneration stages to observe root development on randomly selected plants from each treatment. A small 10-centimeter ruler was used to measure root length after 10 days when the plant roots from other treatments became measurable. Root health was measured through visual inspections and recorded, observing the root vigor of plants in all treatments. Plants used for these assessments were carefully handled and planted back in their cells immediately after use. The overall root development percentage of every treatment was done after 21 days (maximum time period required for rooting of hybrid tea roses) by randomly selecting 10 plants from each treatment.

3.4.2 Measuring shoot development

Hybrid tea roses usually start developing shoots during their early root development stages. Plants to be measured throughout the process were randomly selected within each treatment. A ruler was used to measure and record shoot length whilst visual inspection was used to observe shoot health and vigor. This was monitored and done regularly after every 3 days.

3.5 Data analysis

Appropriate methods were used to perform statistical analysis so as to compare the performance of different rooting media formulations in facilitating root and shoot development as well as comparing the performance of the three cultivars used. A factorial Analysis of Variance (ANOVA) and post-hoc tests were used to determine significant differences in root and shoot development among treatments. Data was analyzed using statistical software.

3.6 Limitations of the study

The research was conducted in a specific geographic region under controlled environment. The variability of soil types especially the clay soils, may influence the root and shoot development process in roses. Future studies should address these limitations by including multi-seasonal and multi-location trials.

CHAPTER 4: RESULTS

4.1 ROOT DEVELOPMENT

In order to observe the time taken by each treatment to undergo root initiation, root development was assessed every two days from the expected time period of root initiation (e.g. 7 to 9 days) up to 21 days when root development is almost constant and the rose plants are about to complete final propagation stage (fourth week).

4.1.1 Root development at 7 days

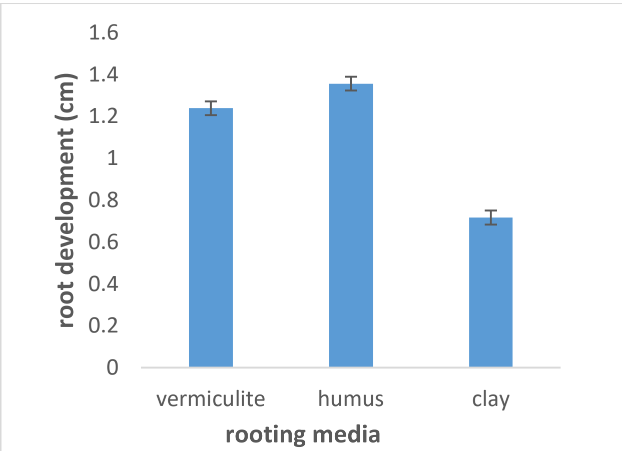

Fig. 4.1. Showing performance of different media in promoting grafted rose root development after 7 days.

As shown in figure 4.1 above, the three rooting media showed a significant difference ($p<0.05$) in initiating root development after seven days, with humus performing better than all followed by vermiculite. Clay had a poor performance.

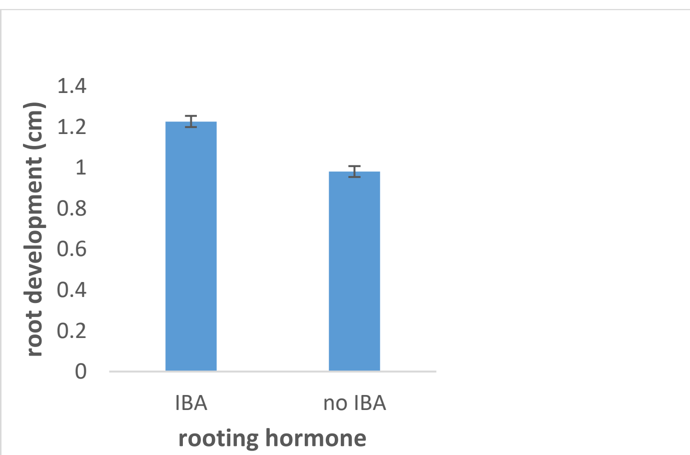

Fig 4.2 showing the effect of Indole 3-butyric acid on root development after 7 days.

After 7 days, there was a significant difference ($p<0.05$) between treatments with Indole Butyric Acid application and those without, as shown in figure 4.2 above. IBA treatments had a significantly higher performance.

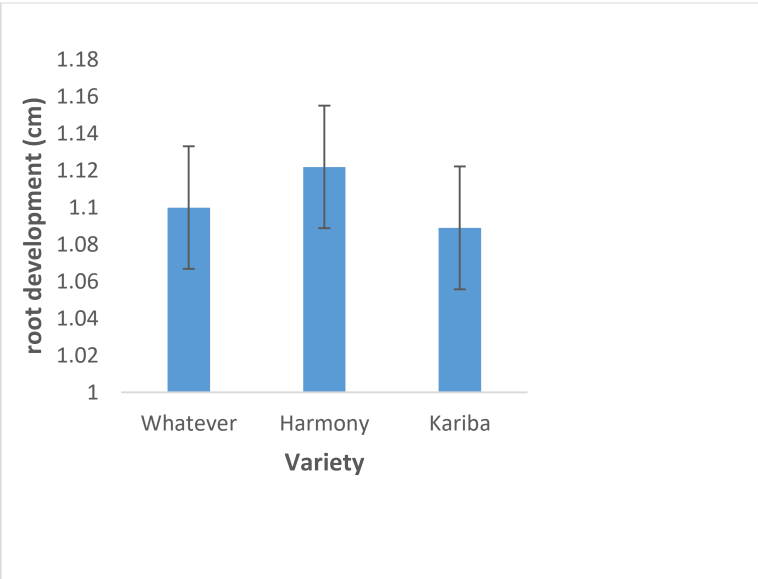

Fig. 4.3. Showing the performance of three different varieties regarding rooting development after 7 days.

The results also stated that after 7 days the treatments showed no significant difference ($p>0.05$) in root development of different varieties, Whatever, Harmony and Kariba. This is illustrated in figure 4.3 above.

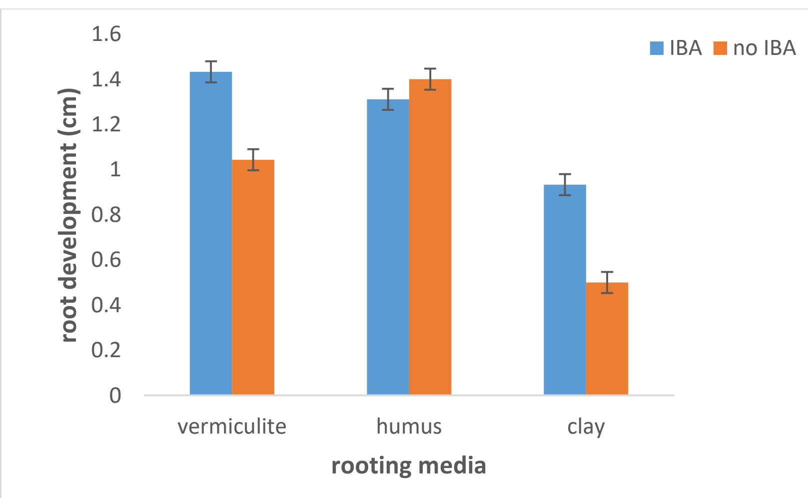

Fig 4.4 showing root development after 7 days, as impacted by interactions of different rooting media with rooting hormone (IBA).

As shown in Fig 4.4 above, vermiculite with IBA had a significantly higher performance than vermiculite without IBA. Humus showed no significant difference (p>0.05) in facilitating root development, regardless of IBA application. Clay with IBA had a significantly higher performance than clay without IBA.

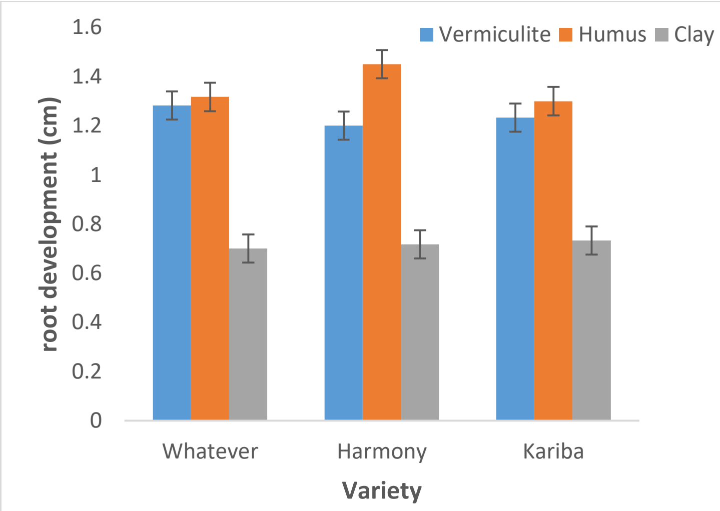

Fig 4.5 showing media-variety interaction impacting root development.

As indicated in figure 4.5 above, vermiculite and humus had no significant difference in promoting root development of variety Whatever. Both vermiculite and humus had a significantly high performance over clay. Humus had a significantly higher performance over vermiculite and clay, in rooting Harmony. Vermiculite and humus had no significant difference in promoting root development of Kariba, whilst, both vermiculite and humus had a significantly high performance over clay.

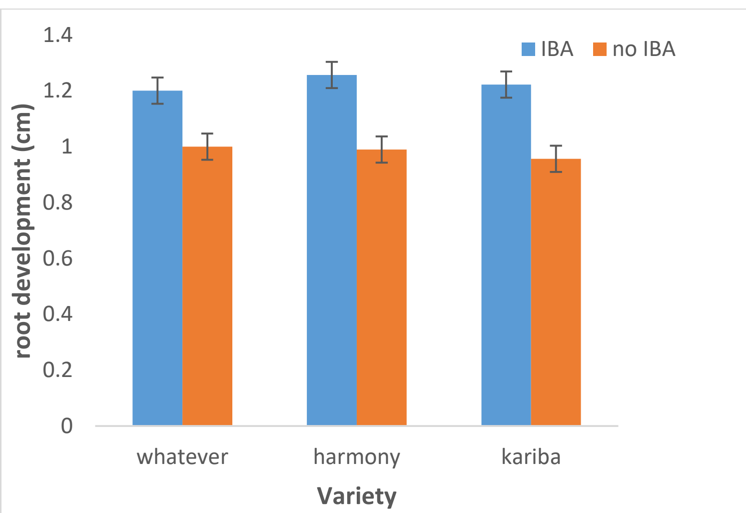

Fig 4.6. Hormone-variety interaction in impacting root development.

As shown in Fig 4.6 above, when treated with IBA, all the varieties had a significantly higher performance than in treatments without IBA.

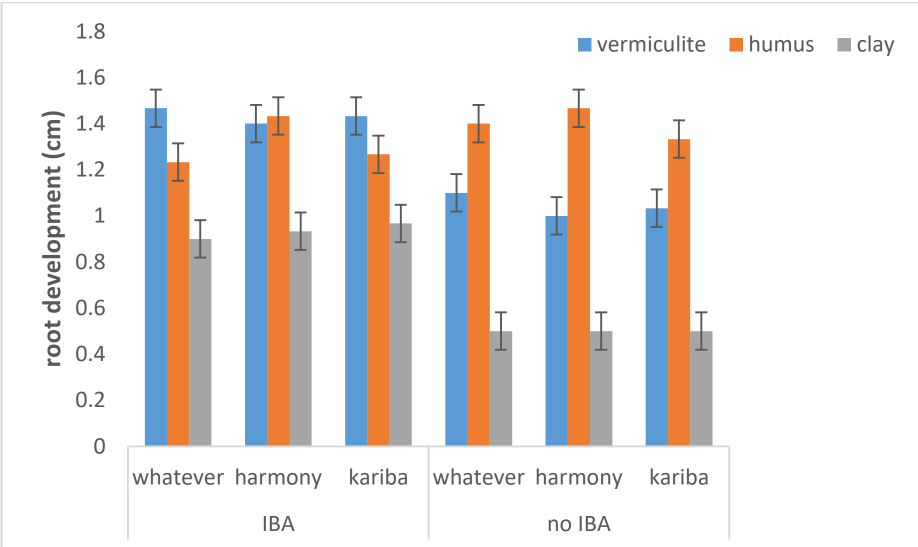

Fig 4.7 Media-hormone-variety interaction.

Whatever, Harmony and Kariba had a significantly higher performance in vermiculite with IBA than in vermiculite with IBA. Whatever, Harmony and Kariba showed no significant difference in humus media, regardless of IBA treatment. Whatever, Harmony and Kariba had a significantly higher performance in clay with IBA as compared to clay without IBA.

4.1.2. Root development at 9 days.

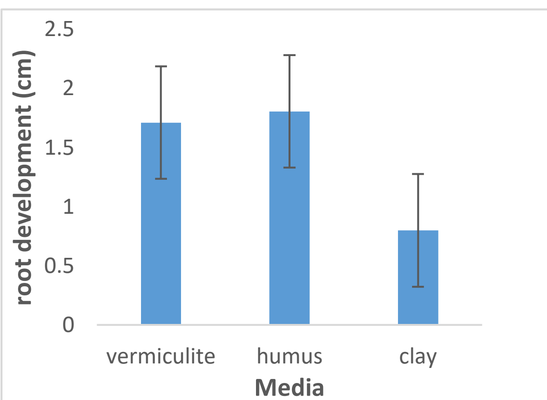

Fig 4.8 Performance of different media in impacting root development at 9 days

As indicated in Figure 4.8 above, vermiculite, humus and clay showed no significant difference.

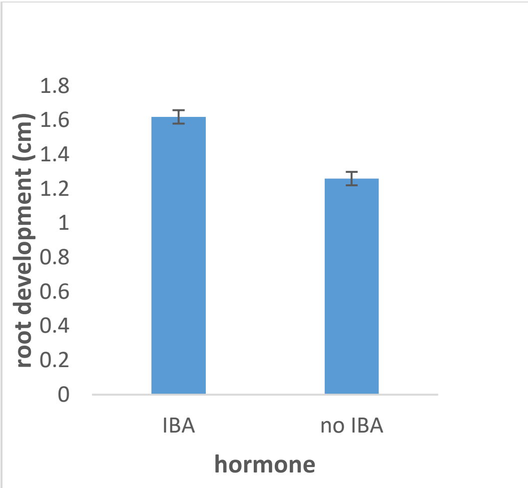

Fig 4.9. Impact of IBA at 9 days.

At nine days there was a significant difference between treatments treated with IBA and those without (p<.001). Treatments with IBA had a significantly higher performance than those without IBA.

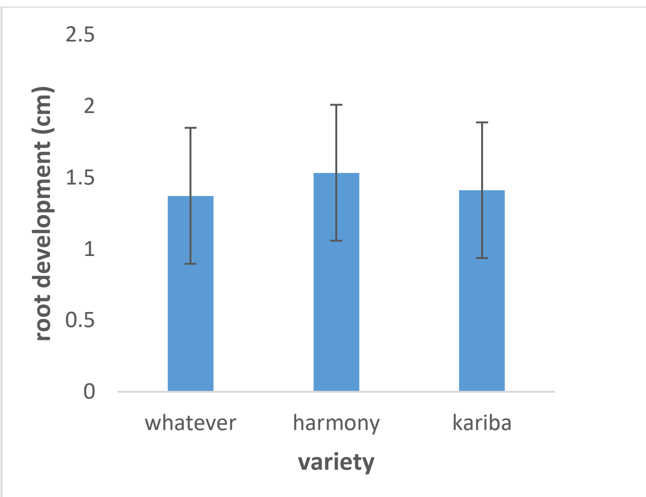

Fig 4.10. Performance of different varieties at 9 days.

There was no significant difference in root development of the three varieties at 9 days, as shown in Fig 4.10 above. The significance level was P>0.05.

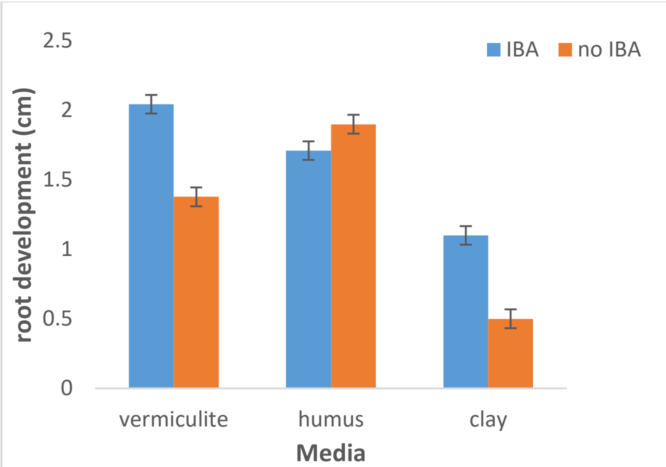

Fig 4.11. Media-hormone interaction in impacting root growth at 9 days.

As shown in Figure 4.11 above, there was a significant difference ($p<.001$) resulted from media-hormone interaction. Vermiculite with IBA had a significantly higher performance than vermiculite without IBA. Humus with IBA had a significantly higher performance than humus without IBA. Clay with IBA had a significantly higher performance than clay without IBA.

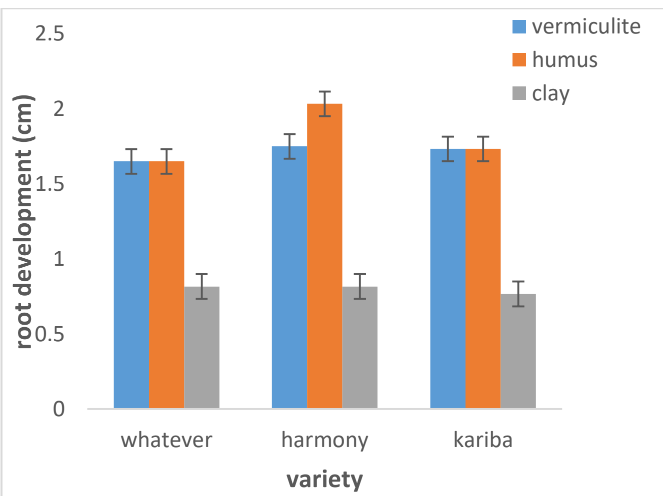

Fig 4. 12. Media-variety interaction impact on root development at 9 days.

As shown in Fig 4.12, vermiculite and humus had no significant difference in facilitating root development of Whatever, whilst, both vermiculite and humus had a significantly higher performance over clay. Humus had a significantly high performance than both vermiculite and clay, in promoting root development of Harmony. Vermiculite and humus had no significant difference in facilitating root development of Kariba, whilst, both vermiculite and humus had a significantly higher performance over clay.

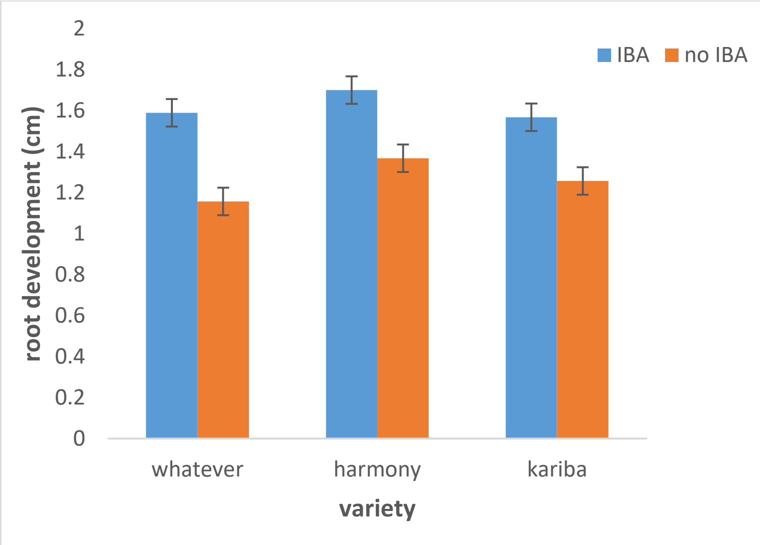

Fig. 4.13. Hormone-variety interaction

At 9 days, the performance of all the three varieties when treated with IBA, was significantly high as compared to those in treatments that weren't treated with IBA.

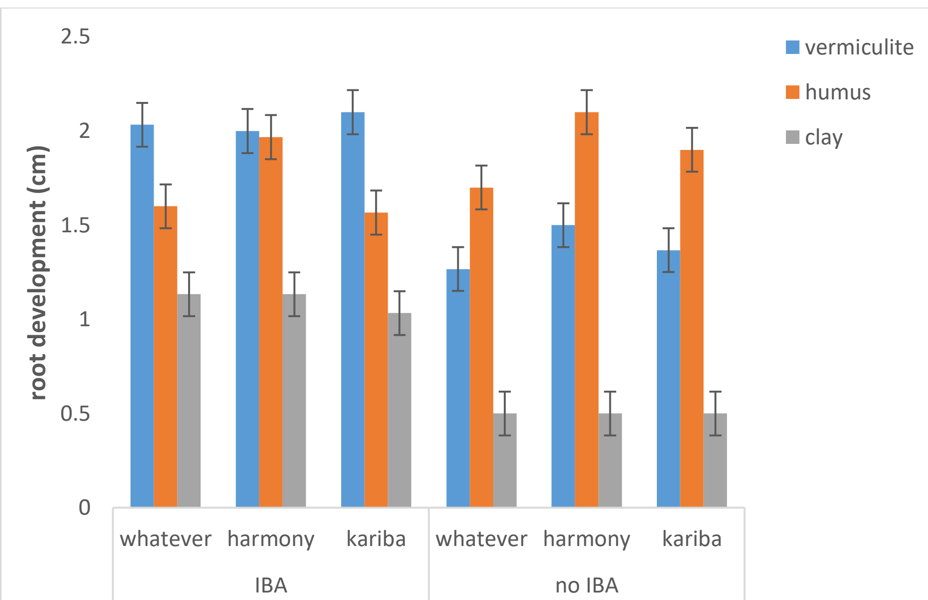

Fig 4.14. Media-hormone-variety interaction impact at 9 days.

Whatever had a significantly higher performance in vermiculite with IBA than in vermiculite without IBA. There was no significant difference between Whatever in humus with IBA and Whatever in humus without IBA. Whatever had a significantly higher performance in clay media with IBA than in clay media without IBA. Harmony had a significantly higher performance in vermiculite with IBA than in vermiculite without IBA. There was no significant difference between Harmony in humus with IBA and Harmony in humus without IBA. Harmony had a significantly higher performance in clay media with IBA than in clay media without IBA. Kariba had a significantly higher performance in vermiculite with IBA than in vermiculite without IBA. Kariba had a significantly higher performance in humus without IBA than in humus with IBA. Kariba had a significantly higher performance in clay media with IBA than in clay media without IBA.

4.1.3 Root development at day 11

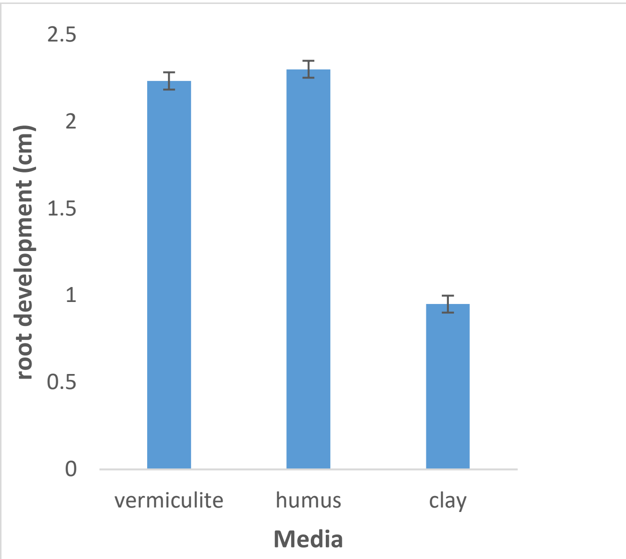

Fig. 4.15. Different media performance at 11 days.

Figure 4.15 above shows that, vermiculite and humus performance wasn't significantly different ($p>0.05$) in facilitating root growth at 11 days. There is a significant difference between Clay and other media.

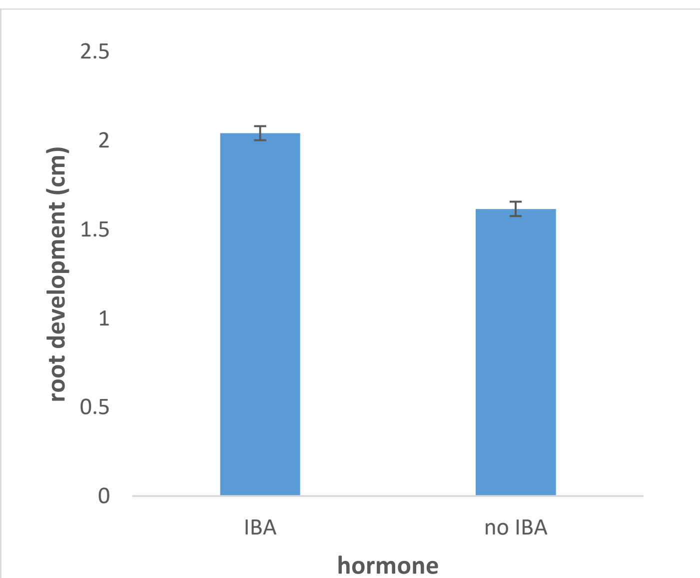

Fig 4.16. Rooting hormone impact on root growth at 11 days.

There was a significant difference in root growth between treatments treated with IBA and those without IBA, as shown in Figure 4.16. P value was less than 0.001.

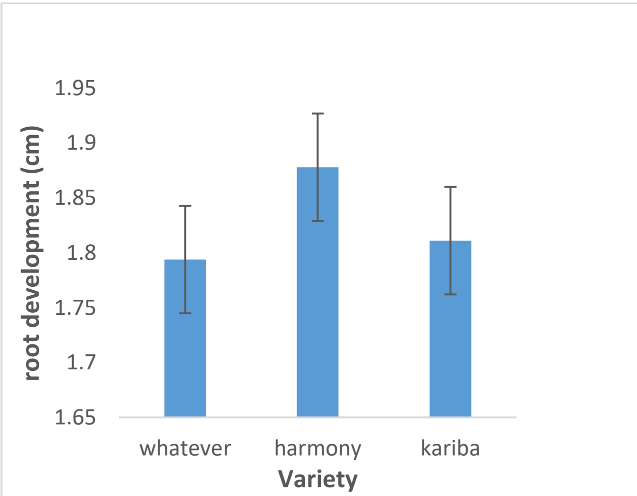

Fig 4.17. Performance of different varieties in root growth at 11 days.

Fig 4.17 above shows that there was no significant difference among all the varieties in terms of root growth after 11 days. The P value was equivalent to 0.454.

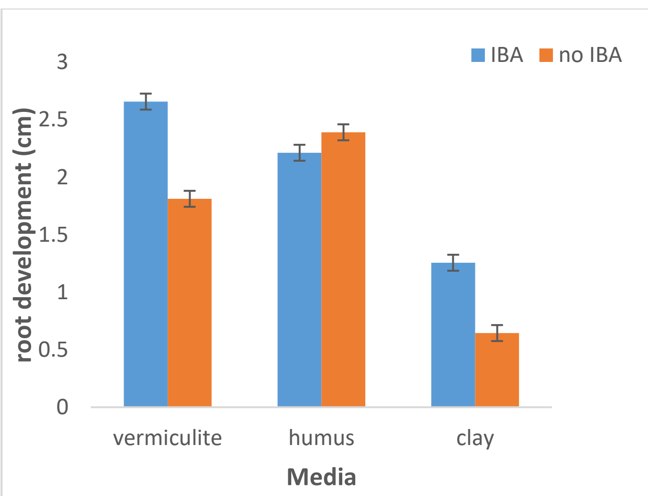

Fig 4.18. Media-hormone interaction impact on root growth at 11 days.

As shown in figure 4.18 above, vermiculite with IBA had a significantly high performance than vermiculite without IBA. There was no significant difference between humus with IBA and humus without IBA. Clay with IBA had a significantly high performance than vermiculite without IBA.

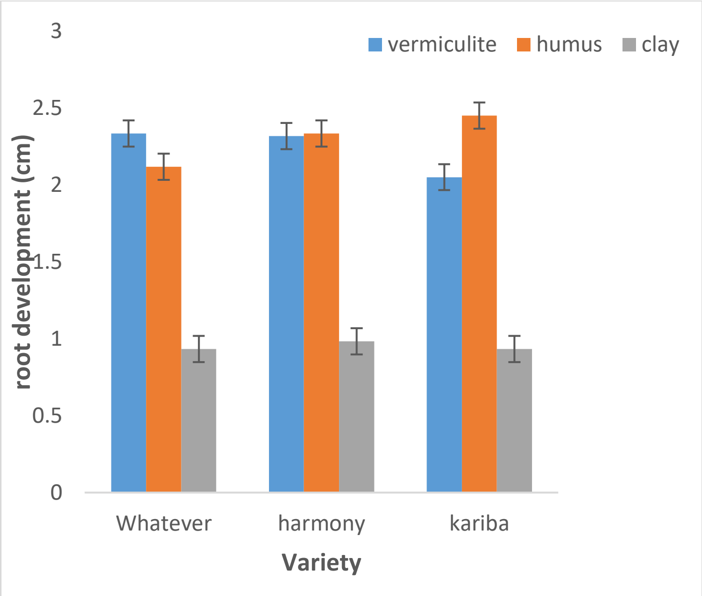

Fig 4.19. Media-variety interaction impact on root growth at 11 days.

As shown in Fig 4.19 above, Whatever had a significantly high performance in vermiculite than in humus and clay. Harmony did not significantly differ in vermiculite and humus, but its performance in the two was significantly higher than in clay. Kariba had a significantly high performance in vermiculite than in humus and clay.

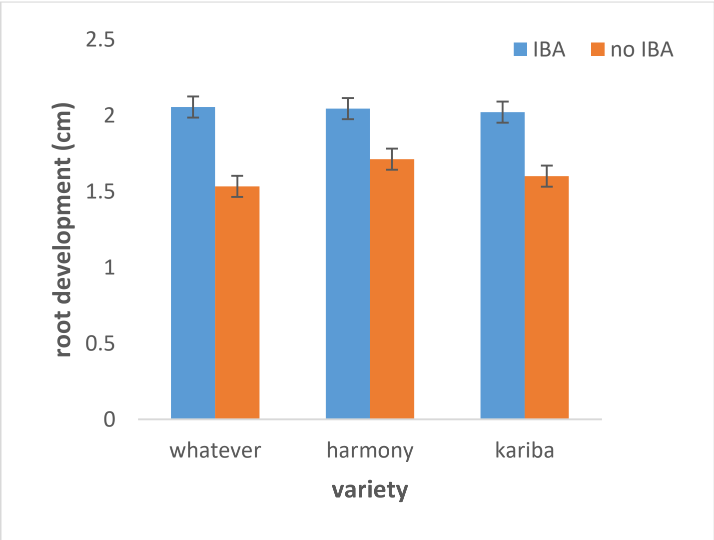

Fig 4.20. Hormone-variety interaction on root growth at 11 days.

Fig 4.20 above shows that all varieties respond almost similarly to IBA application, therefore, there was a significantly higher performance in varieties in treatments with IBA as compared to treatments without IBA.

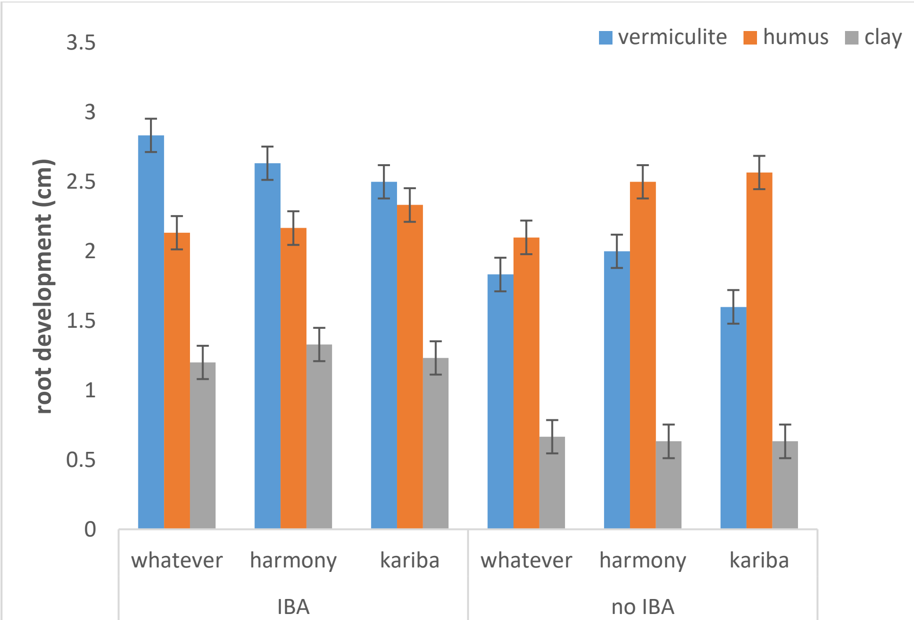

Fig 4.21. Media-hormone-variety interaction impact on root growth at 11 days.

Whatever, Harmony and Kariba, had a significantly higher performance in vermiculite with IBA than in vermiculite without IBA. Whatever and Kariba showed no significant difference in humus with IBA and in humus without IBA. Whatever, Harmony and Kariba, had a significantly higher performance in clay media with IBA than in clay media without IBA. Harmony had a significantly higher performance in humus without IBA than in humus with IBA.

4.1.3 Root development at 13 days

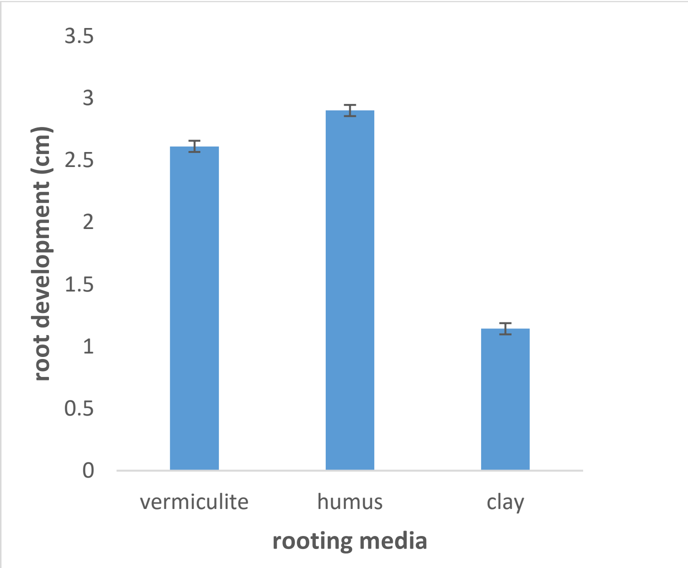

Fig 4.22. Root development after 13 days as impacted by different rooting media.

After 13 day, humus had a significantly higher performance as compared to vermiculite and clay, whilst, vermiculite also had a significantly higher performance than clay, as shown in Fig 4.22 above.

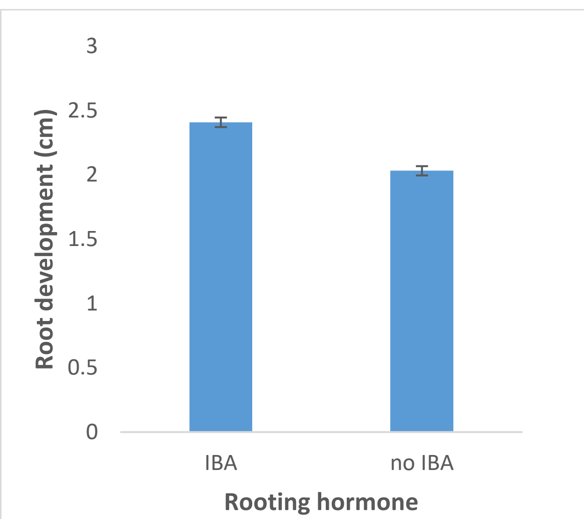

Fig 4.23. Rooting hormone impact on root development after 13 days.

As illustrated in figure 4.23, treatments that were treated with IBA had a significantly higher performance than the treatments without IBA. Indole Butyric acid effect was significant ($p<0.001$).

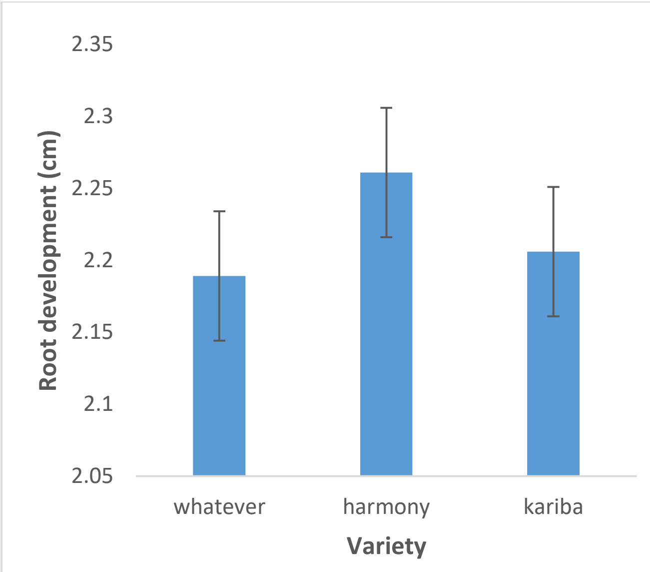

Fig 4.24. Performance of three different varieties in developing roots.

After 13 days, all the three varieties (Whatever, Harmony and Kariba) showed no significant difference between each other in terms of root growth and development, meaning that, the type of cultivar had no significant effect on the rooting of grafted rose plants.

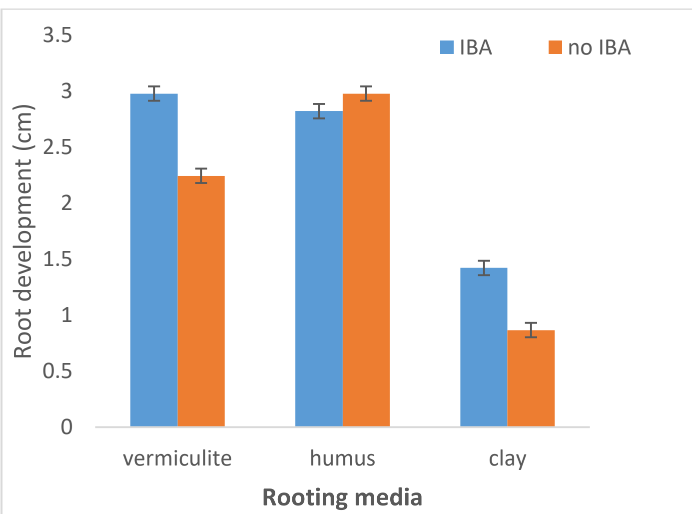

Fig 4.25. Showing media-hormone interaction impact on root growth and development

Each rooting media performed differently when applied with rooting hormone and when without rooting hormone application, as shown in Fig 4.25 above. In other words, root development was significantly different ($p<0.001$) in the same media as influenced by IBA application. Vermiculite with IBA had a significantly higher performance than vermiculite without IBA. Humus without IBA performed significantly better than humus with IBA. Performance of clay with IBA was significantly higher as compared to clay without IBA.

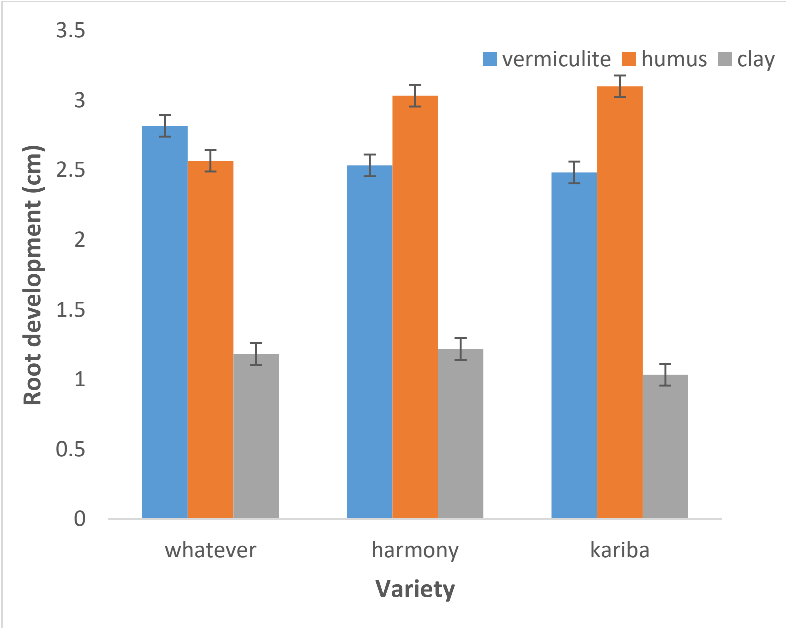

Fig 4.26. Showing media-variety interaction impact on root growth at 13 days.

Fig 4.25 shows that, Whatever had a significantly higher performance in vermiculite than in humus and clay. Harmony had a significantly higher performance in humus than in vermiculite and clay. Kariba had a significantly higher performance in humus than in vermiculite and clay.

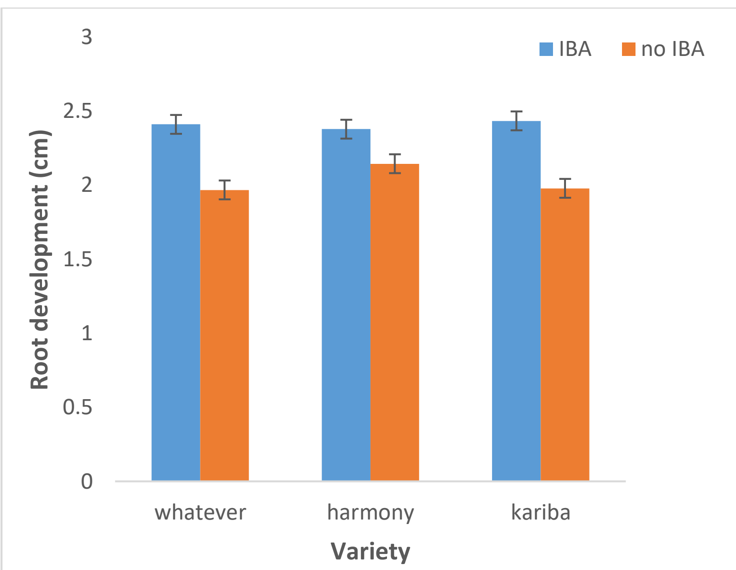

Fig 4.27. Hormone-variety interaction impact at 13 days.

As shown in Fig 4.26 above, Variety Whatever, performed significantly high in IBA treatments as compared to treatments without IBA. Harmony also performed significantly higher in IBA treatments than in treatments without IBA. Kariba also did the same. In other words, all the varieties performed higher in treatments with IBA whilst performing lower in treatments without IBA.

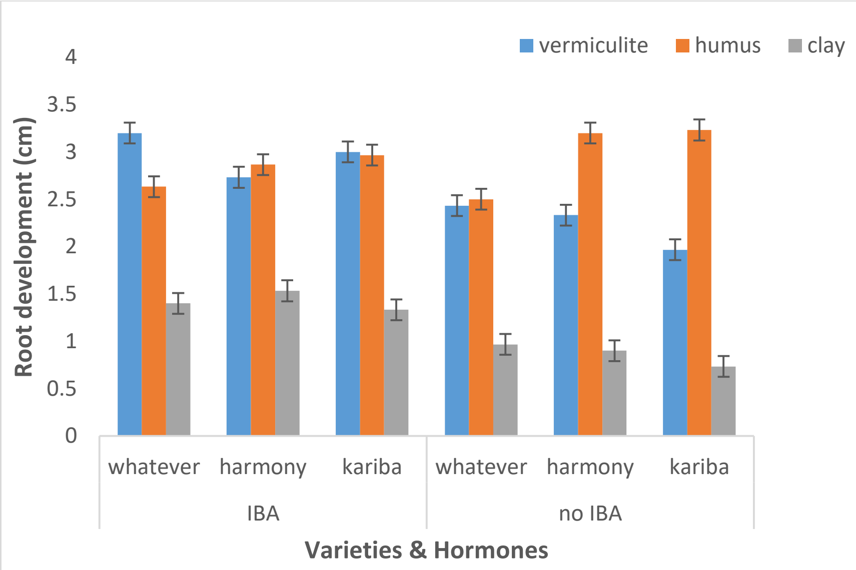

Fig 4.28 showing interaction of media, hormone and variety in impacting root growth at 13 days.

Whatever, Harmony and Kariba, had a significantly higher performance in vermiculite with IBA than in vermiculite without IBA. Whatever showed no significant difference in humus with IBA and in humus without IBA. Whatever, Harmony and Kariba, had a significantly higher performance in clay media with IBA than in clay media without IBA. Harmony and Kariba had a significantly higher performance in humus without IBA than in humus with IBA.

4.1.5 Root development at 15 days

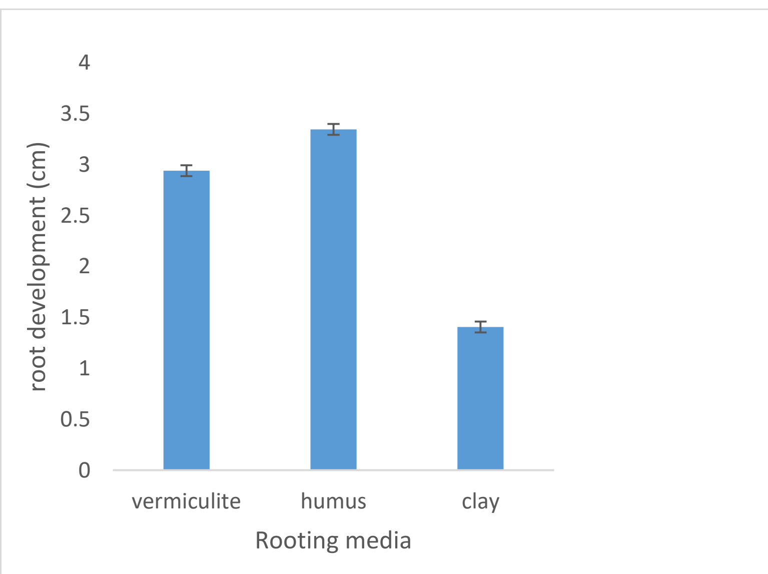

Fig 4.29 shows performance of different rooting media at 15 days.

As indicated on Fig 4.28 above, humus had a significantly higher performance as compared to both vermiculite and clay. All the three rooting media showed a significant difference from each other ($p<0.05$).

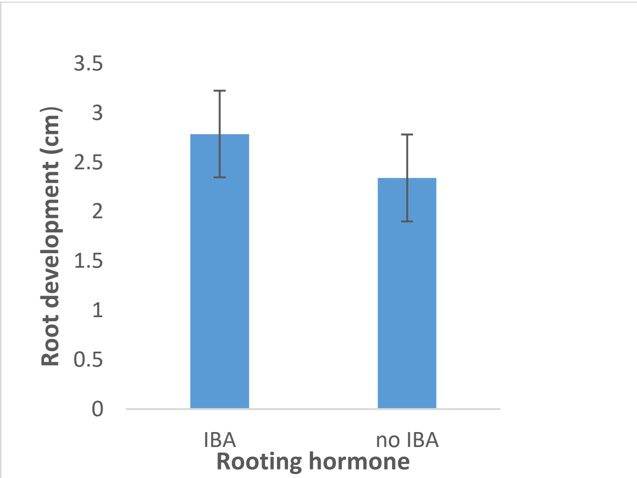

Fig 4.30 showing the impact of rooting hormone, IBA, at day 15.

As indicated in Figure 4.29 above, at day 15, there was no significant difference in impacting root growth between treatments with IBA and those without.

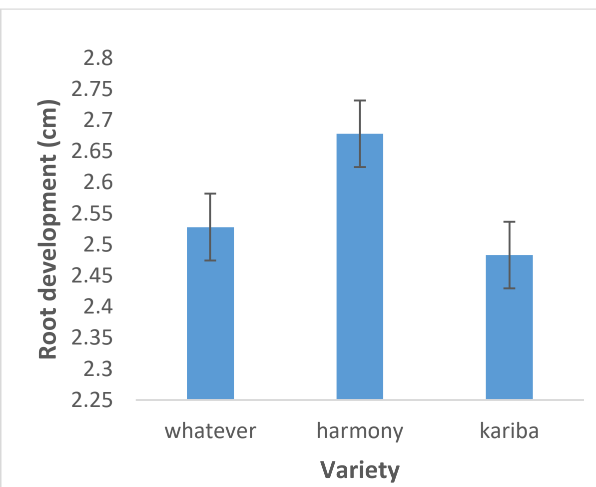

Fig 4.31 showing performance of three varieties at 15 days.

As shown in Fig 4.30 above, Harmony exhibited a significantly higher performance as compared to Whatever and Kariba at day 15. There is no significant performance difference between Whatever and Kariba.

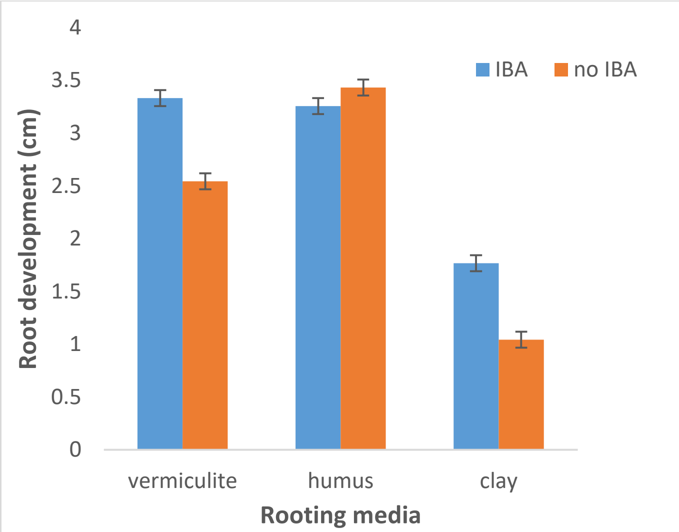

Fig 4.32 showing media-hormone interaction impact on root growth at day 15.

As shown in Fig 4.31 above, vermiculite with IBA had a significantly higher performance than vermiculite without IBA. There was no significant difference in performance between humus with IBA and humus without IBA. Clay with IBA was significantly superior to clay without IBA.

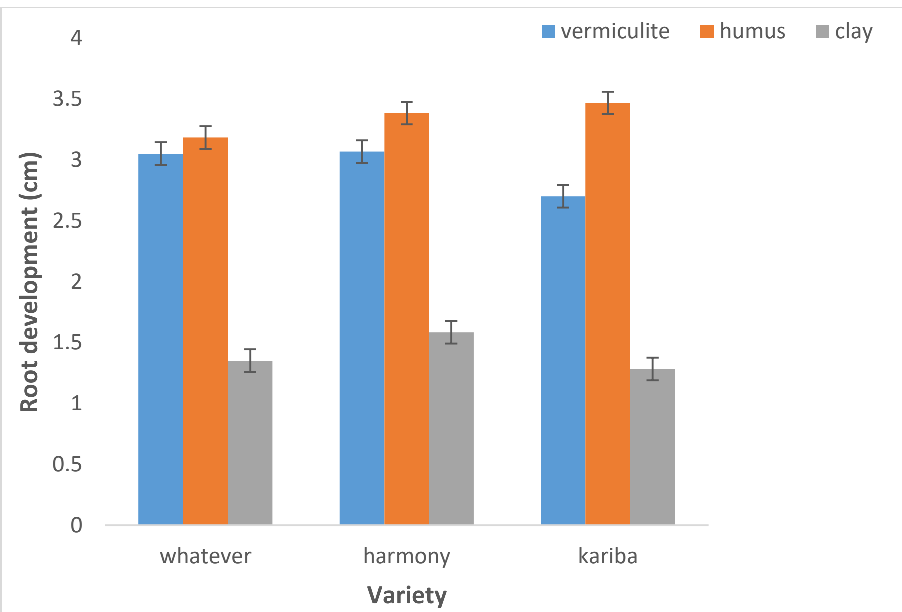

Fig 4.33 showing Media-variety interaction impact on root growth at 15 days.

The above figure shows that, performance of variety Whatever in humus is not significantly different from in vermiculite. The performance of Whatever in humus and vermiculite is significantly high as compared to in clay. Harmony in humus exhibited a significantly high performance as compared to harmony in vermiculite and clay. Kariba also showed a significantly higher performance in Humus than in vermiculite and clay.

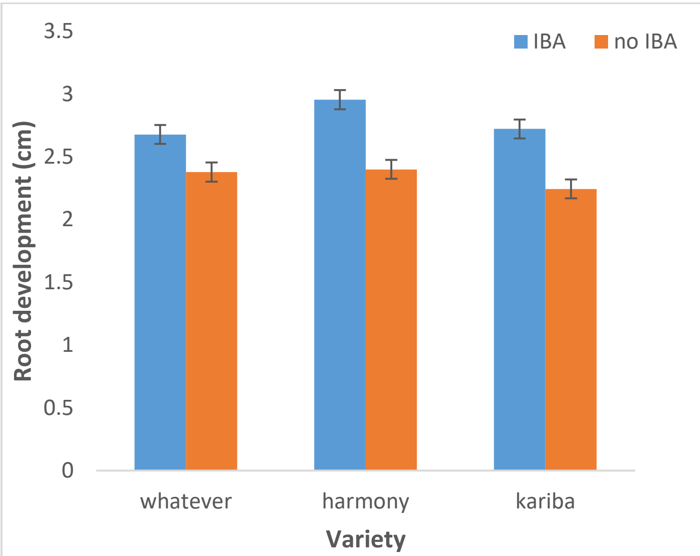

Fig 4.34 showing Hormone-variety interaction impact at 15 days.

As indicated in figure 4.33, all the varieties treated with IBA were significantly superior to those without IBA treatment. There was a significant difference ($p<0.05$).

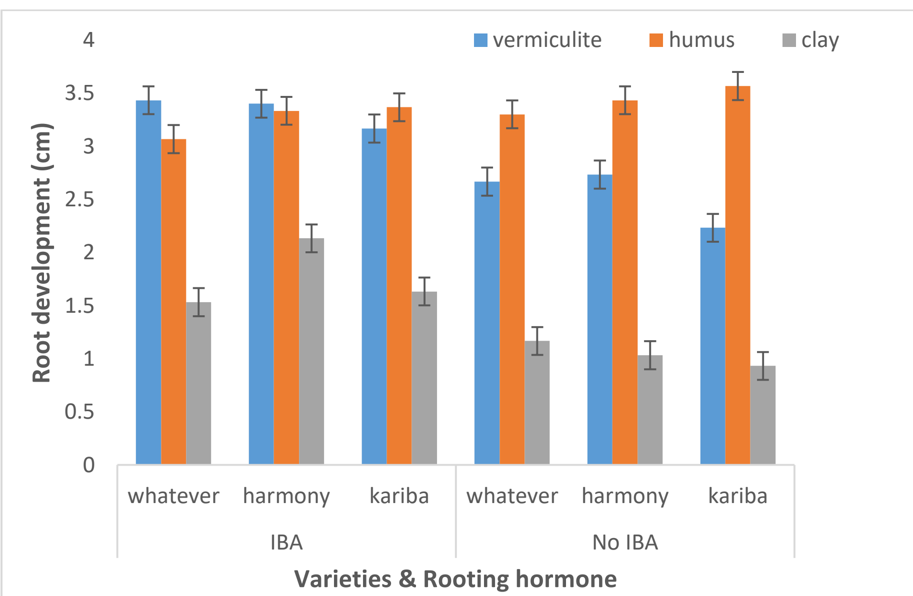

Fig 4.35 showing media-hormone-variety interaction impact at 15 days.

As illustrated in fig 4.34, Whatever had a significantly higher performance in vermiculite with IBA than in vermiculite without IBA. There was no significant difference between Whatever in humus with IBA and Whatever in humus without IBA. Whatever also performed significantly higher in clay with IBA than in clay without IBA.

Harmony performed significantly higher in vermiculite with IBA than in vermiculite without IBA. There was no significant difference between Harmony in humus with IBA and Harmony humus without IBA. Harmony also had a significantly higher performance in clay with IBA than in clay without IBA.

Kariba had a significantly higher performance in vermiculite with IBA than in vermiculite without IBA. There was no significant difference in performance between Kariba in humus with IBA and Kariba in humus without IBA. Kariba had a significantly higher performance in clay with IBA in clay without IBA.

4.1.6 Root development at 17 days

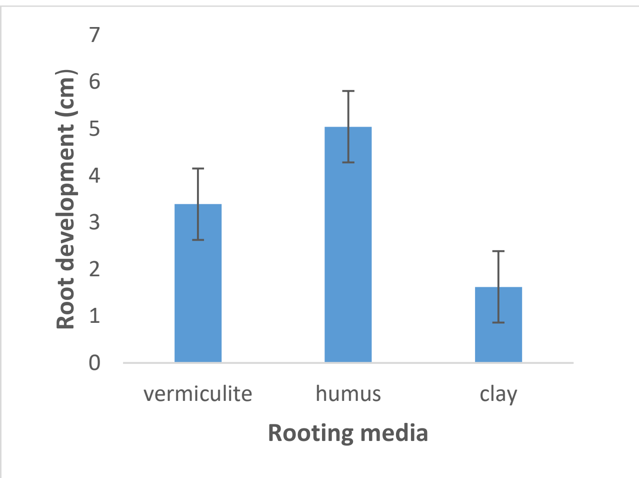

Fig 4.36 showing rooting media impact on root growth at 17 days.

Humus had a significantly higher performance as compared to vermiculite and clay. Vermiculite performed significantly higher than clay. This is illustrated in Fig 4.36 above.

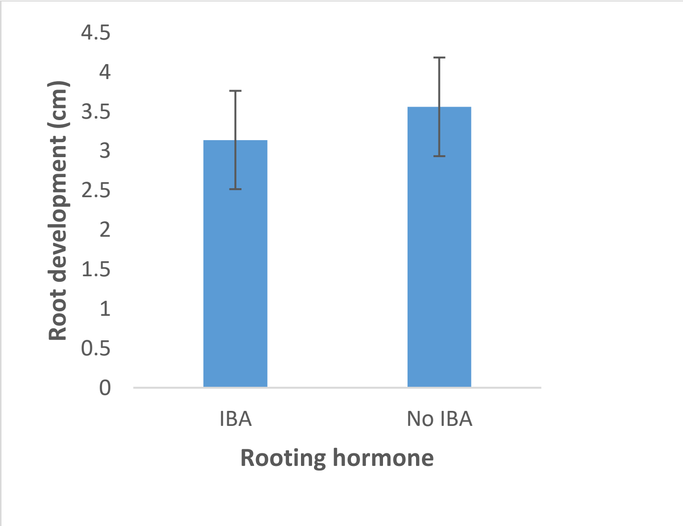

Fig 4.37 showing rooting hormone impact on root growth at 17 days.

There was no significant difference between treatments with IBA and treatments without IBA, in promoting root growth and development at day 17.

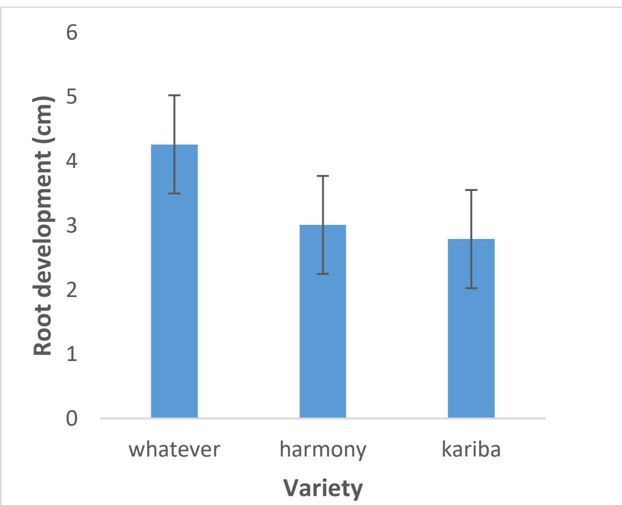

Fig 4.38 showing root growth of three varieties at 17 days.

There was no significant difference (p=0.39) in root development between Whatever and Harmony, Whatever and Kariba, and also Harmony and Kariba.

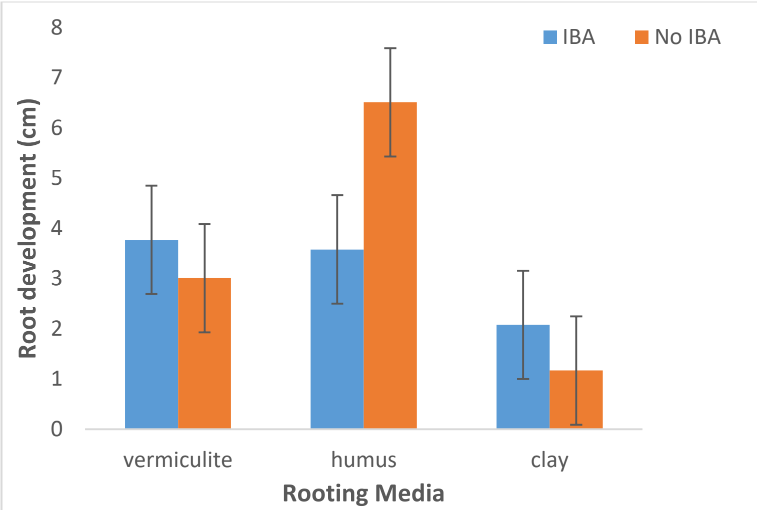

Fig 4.39 showing Media-hormone interaction impact on root growth at 17 days.

There was no significant difference between vermiculite with IBA and without IBA. Humus without IBA exhibited a significantly higher performance than humus with IBA. Clay showed no significant difference regardless of IBA application.

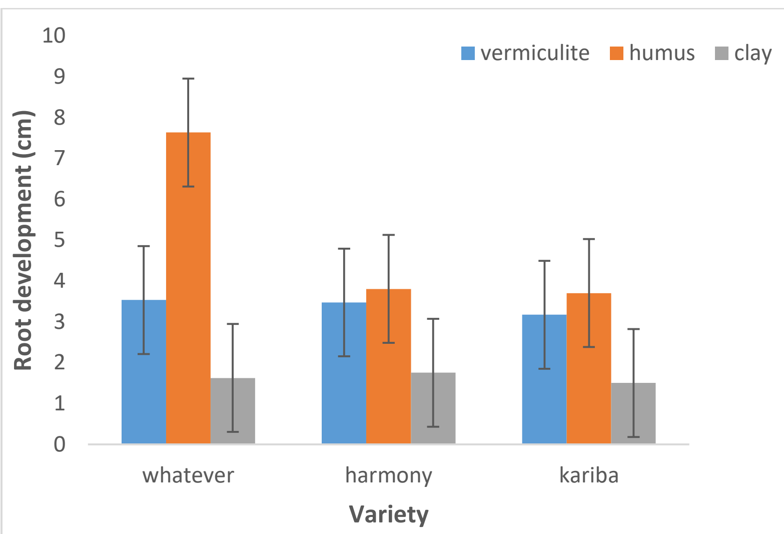

Fig 4.40 showing impact of media-variety interaction on root growth.

As shown in Figure 4.40, Whatever had a significantly higher performance in humus than in vermiculite and clay. There was no significant difference between Whatever in vermiculite and in clay. Vermiculite, humus and clay exhibited no significant difference in promoting root development of Harmony. All the rooting media also exhibited no significant difference in promoting root development of Kariba.

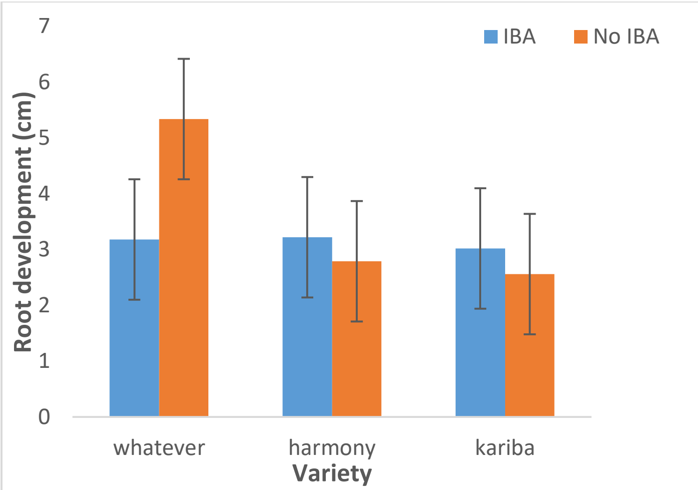

Fig 4.41 showing impact of hormone-variety interaction on root development.

All the varieties showed no significant difference in root development and growth regardless of IBA application.

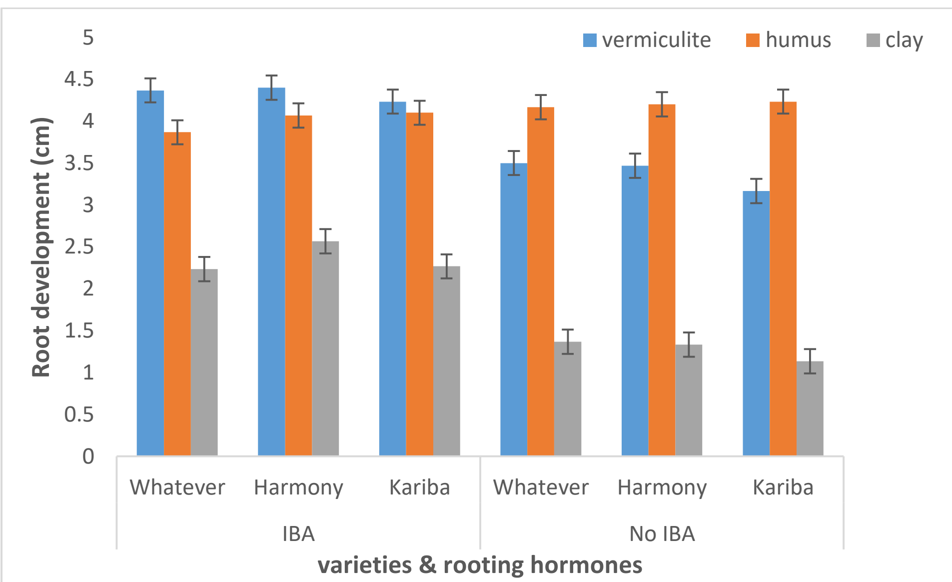

Fig 4.42 showing the impact of media-hormone-variety interaction, on root growth and development at 19 days.

Whatever, Harmony and Kariba, had a significantly higher performance in vermiculite with IBA than in vermiculite without IBA. Whatever, Harmony and Kariba showed no significant difference in humus with IBA and in humus without IBA. Whatever, Harmony and Kariba, had a significantly higher performance in clay media with IBA than in clay media without IBA.

4.1.7 Root development at 19 days.

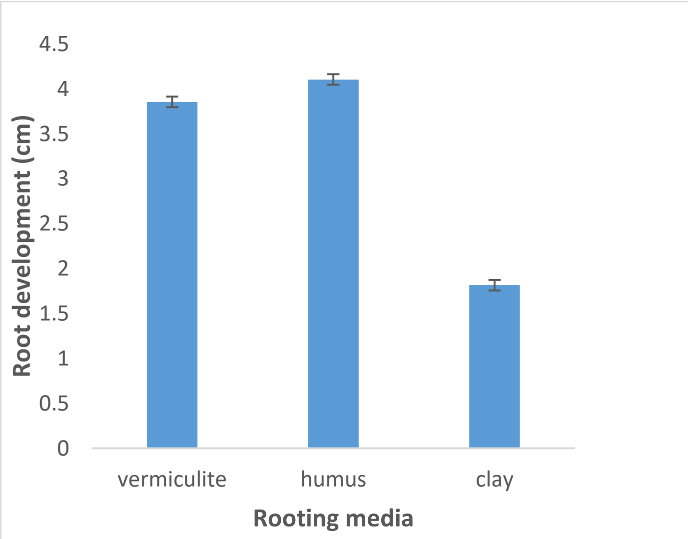

Fig 4.43 showing rooting media impact on root growth at day 19.

Humus showed a significantly higher performance than vermiculite and clay. Vermiculite also exhibited a significantly higher performance as compared to clay. P value was less than 0.001.

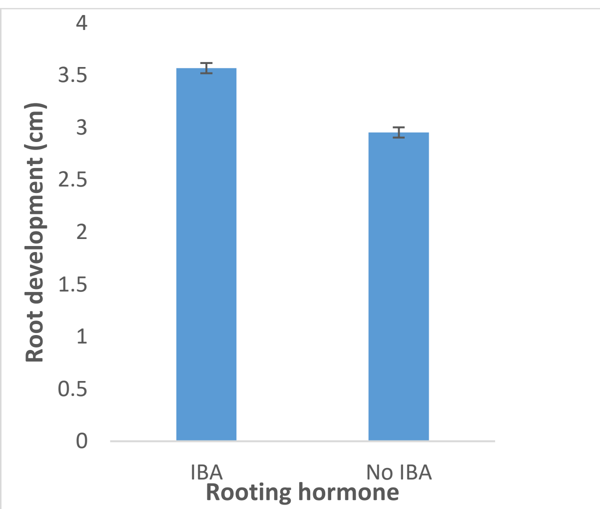

Fig 4.44 showing rooting hormone impact on root growth at day 19.

As shown in the fig above, treatments with Indole 3-Butyric acid (IBA) had a significantly higher performance than those without ($p<0.001$).

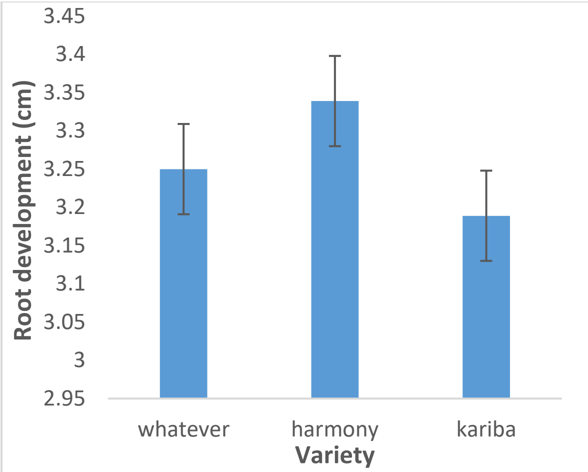

Fig 4.45 showing root development of different varieties after 19 days.

As shown in Fig 4.45 above, there was no significant difference in root growth and development between Whatever and Harmony, and also between Whatever and Kariba. Harmony exhibited a significantly higher performance over Kariba.

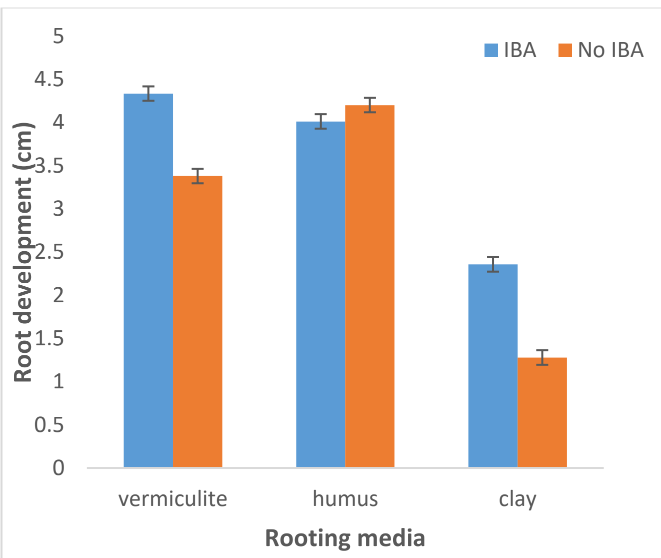

Fig 4.46 showing media-hormone impact on root development at 19 days.

Fig 4.46 above shows that, vermiculite with IBA exhibited a significantly higher performance over vermiculite without IBA. There was no significant performance difference between humus with IBA and humus without IBA. Clay with rooting hormone had a significantly higher performance than clay without rooting hormone.

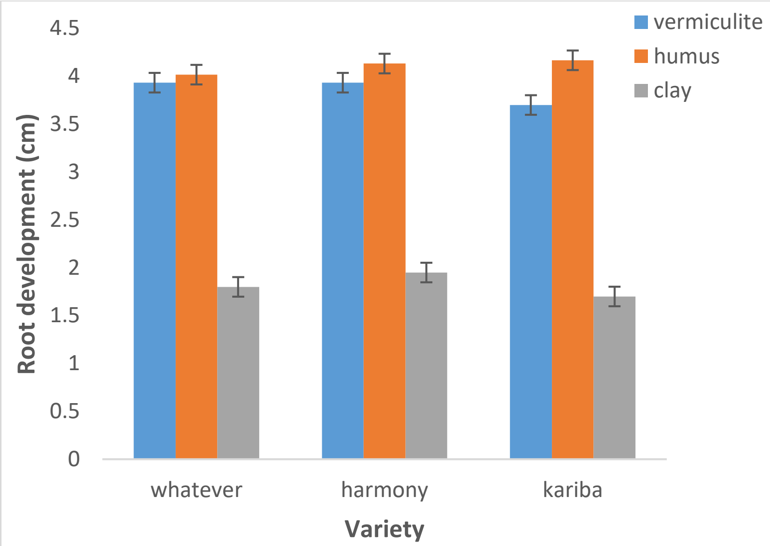

Fig 4.47 showing media-variety interaction impact on root development after 19 days.

As shown in figure 4.47 above, there was no significant difference between Whatever in vermiculite and in humus. Whatever in both vermiculite and humus treatments showed a significantly higher performance as compared to Whatever in clay media.

Harmony showed no significant performance in humus and vermiculite. Harmony in both vermiculite and humus treatments performed significantly higher than in clay. Kariba in humus media performed significantly higher than in vermiculite and clay. Kariba in vermiculite also showed a significantly higher performance as compared to Kariba in clay media.

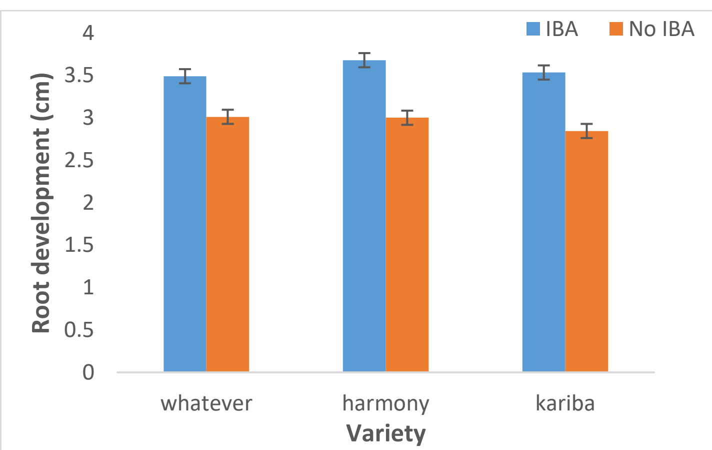

Fig 4.48 showing hormone-variety interaction impact on root development at 19 days.

All the varieties in treatments with IBA had a significantly higher performance as compared to the treatments without IBA. P = 0.374.

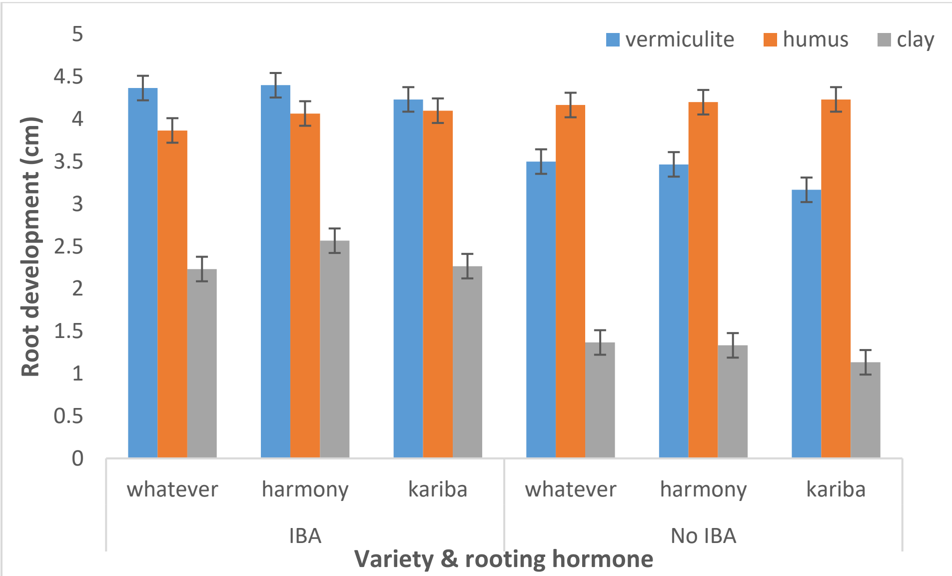

Fig 4.49 showing media-hormone-variety interaction impact on root growth after 19 days.

On the above figure, Whatever in vermiculite with IBA performed significantly higher than Whatever in vermiculite without IBA. There was no significant difference between Whatever in humus with IBA and Whatever in humus without IBA. Whatever in clay with IBA showed a significantly higher performance than Whatever in clay without IBA.

Harmony in vermiculite with IBA performed significantly higher than in vermiculite without IBA. There was no significant difference between Harmony in humus with IBA and Harmony in humus without IBA. Harmony had a significantly high performance in clay with IBA than in clay without IBA.

Kariba performed significantly higher in vermiculite with IBA than in vermiculite without IBA. There was no significant difference between Kariba in humus with IBA and Kariba in humus without IBA. Kariba also had a significantly higher performance in clay with IBA than in clay without IBA.

4.1.8 Root development at 21 days.

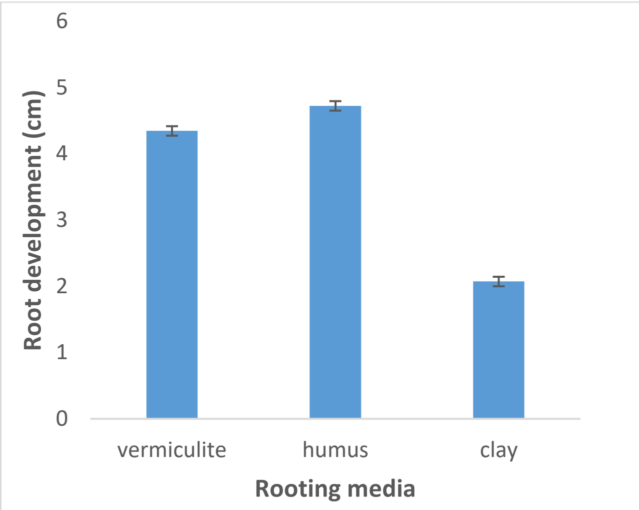

Fig 4.50 showing root development impacted by different rooting media.

Humus had a significantly higher performance than vermiculite and clay. Vermiculite had a significantly higher performance than clay.

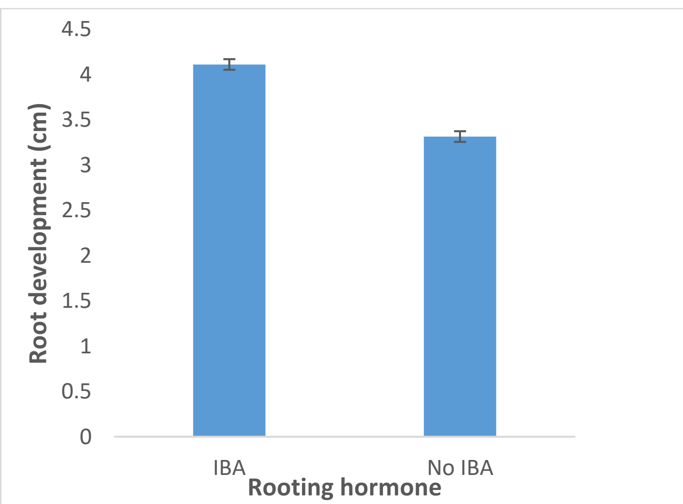

Fig 4.51 showing the impact of rooting hormone on root development.

Treatments with Indole 3-Butyric acid (IBA) had a significantly higher performance than treatments without IBA.

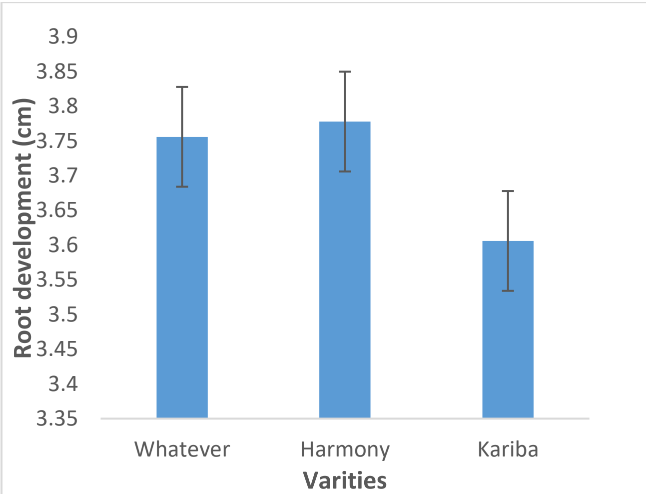

Fig 4.52 showing performance of the three varieties.

There was no significant performance difference between Whatever and Harmony. Both Whatever and Harmony showed a significantly higher performance than Kariba.

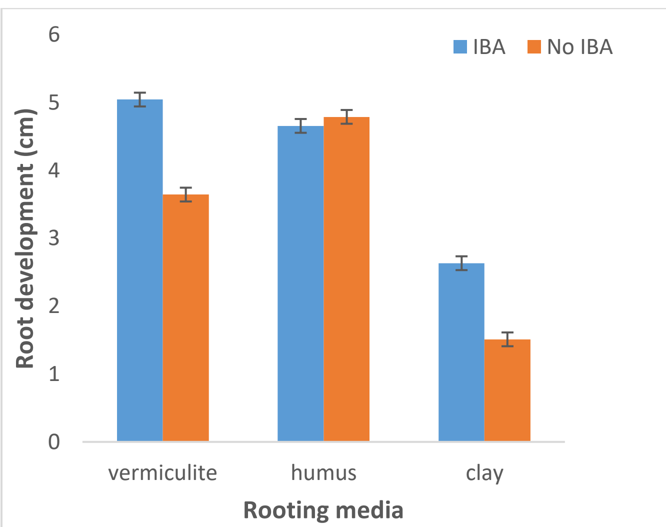

Fig 4.53 showing media-hormone interaction impact on root development.

Vermiculite with IBA performed significantly higher than vermiculite without IBA. There was no significant difference between humus with IBA and humus without IBA. Clay with IBA exhibited a significantly higher performance over clay without IBA.

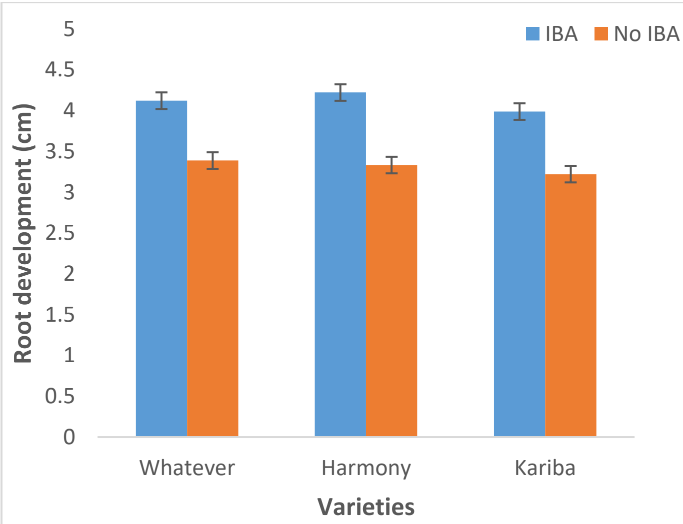

Fig 4.54 showing hormone-variety interaction impact on root development.

Whatever treated with IBA had a significantly higher performance than Whatever without IBA. Harmony treated with IBA had a significantly higher performance than Harmony without IBA. Kariba treated with IBA had a significantly higher performance than Kariba without IBA.

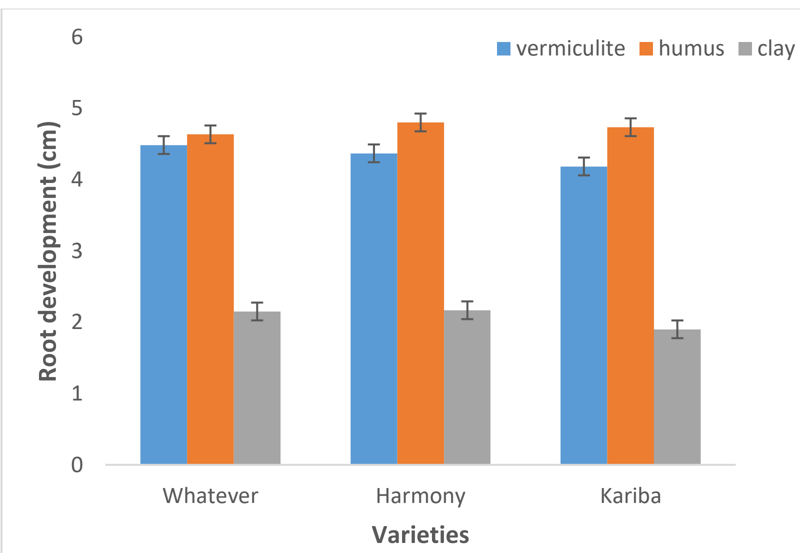

Fig 4.55 showing media-variety interaction impact on root development.

There was no significant difference between vermiculite and humus in promoting root development of variety Whatever. Both vermiculite and humus had a significantly higher performance in promoting rooting of Whatever than clay media.

Humus showed a significantly high performance over vermiculite in promoting root development of variety Harmony. Vermiculite also showed a significantly higher performance over clay in promoting root development of Harmony.

Humus showed a significantly higher performance than vermiculite in root development process of Kariba. Vermiculite also showed a significantly higher performance over clay in promoting root development of Kariba.

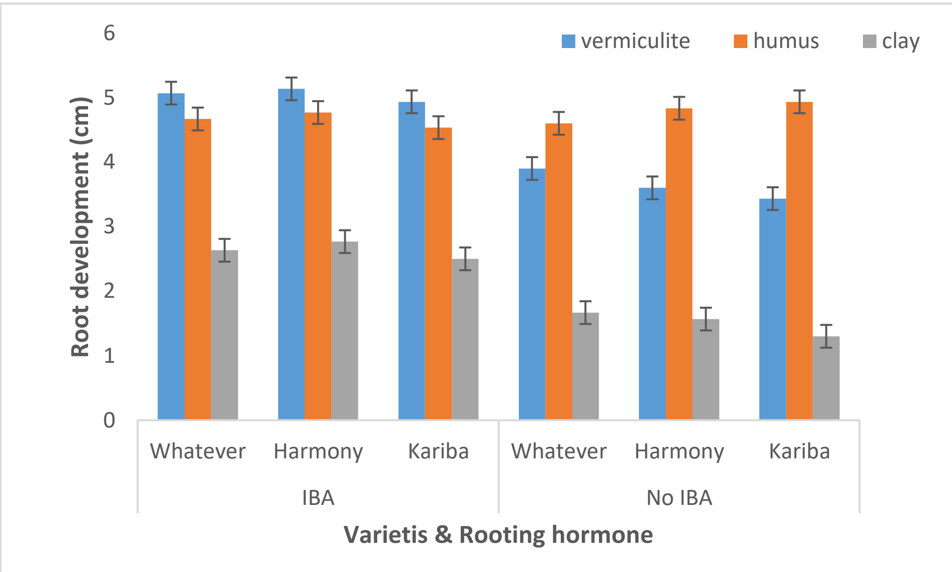

Fig 4.56 showing root development as impacted by media-hormone-variety interaction.

Whatever showed a significantly higher performance in vermiculite with IBA than in vermiculite without IBA. Humus exhibited no significant difference in promoting root development of Whatever, regardless of IBA application. Clay treated with IBA had a significantly higher performance in promoting rooting of Whatever, than clay without IBA.

Vermiculite with IBA showed a significantly high performance in promoting root development of Harmony, as compared to vermiculite without IBA. Humus exhibited no significant difference in promoting root development of Harmony, regardless of IBA application. Clay treated with IBA had a significantly higher performance in promoting rooting of Harmony, than clay without IBA.

Kariba showed a significantly higher performance in vermiculite with IBA than in vermiculite without IBA. Humus exhibited no significant difference in promoting root development of Kariba, regardless of IBA application. Clay treated with IBA had a significantly higher performance in promoting rooting of Harmony, than clay without IBA.

4.2 SHOOT DEVELOPMENT

4.2.1 Shoot development at 21 days.

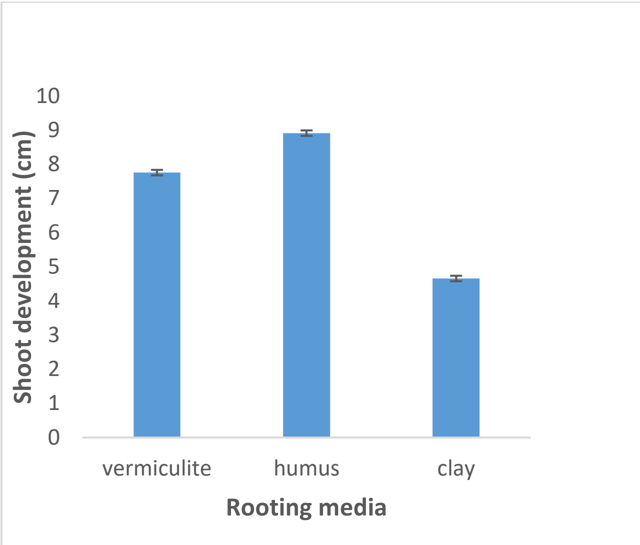

Fig 4.57 showing shoot growth as influenced by rooting media.

As shown on the figure 4.57, humus had a significantly higher performance as compared to vermiculite and clay. Vermiculite had a significantly higher performance as compared to clay.

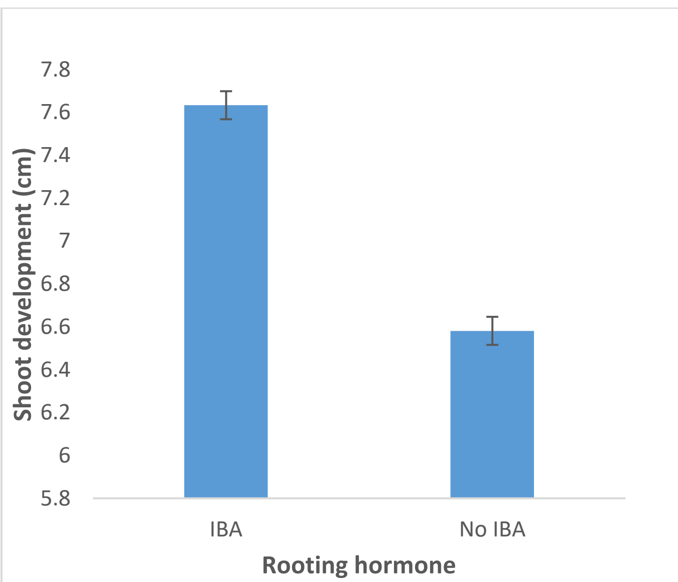

Fig 4.58 showing rooting hormone effects on shoot development.

Treatments with IBA had a significantly higher performance than treatments without IBA, as shown in figure 4.58.

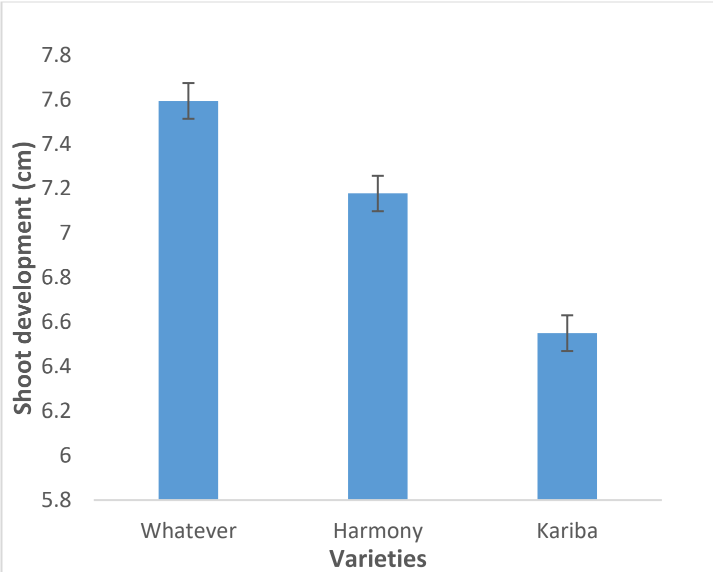

Fig 4.59 showing shoot development of the three roses varieties.

As illustrated in figure 4.59, Whatever had a significantly high performance than Harmony and Kariba. Harmony had a significantly high performance than Kariba.

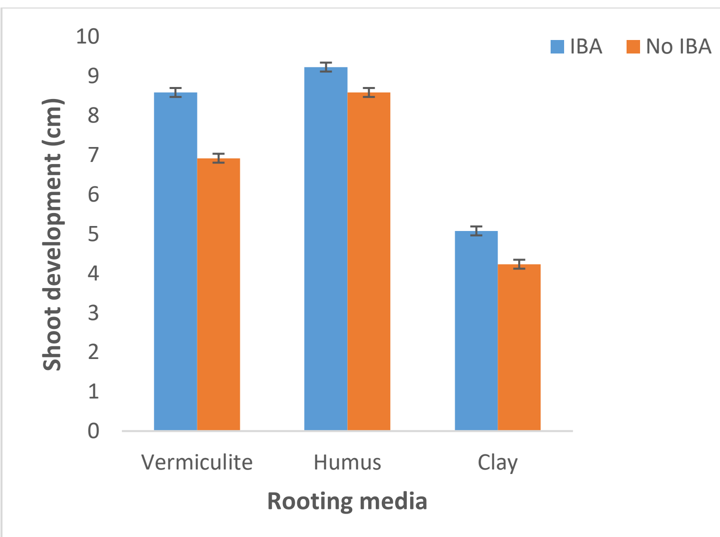

Fig 4.60 showing the impact of rooting media-hormone interaction on shoot development.

As shown in figure 4.60, vermiculite with IBA had a significantly high performance over vermiculite without IBA. Humus with IBA had a significantly high performance over humus without IBA. Clay with IBA had a significantly high performance over clay without IBA.

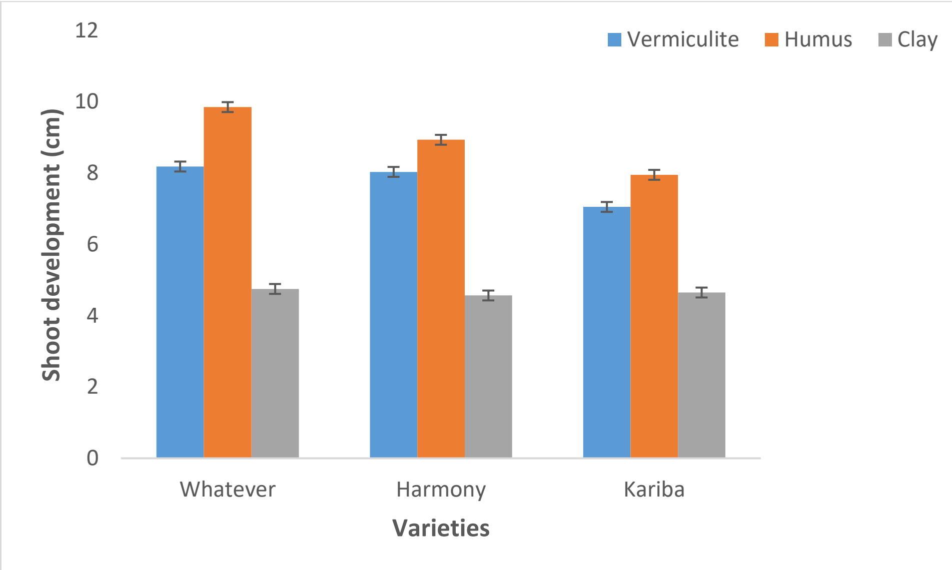

Fig 4.61 showing shoot development as impacted by rooting media-variety interaction.

Figure 4.61 above shows that, Whatever, Harmony and Kariba performed significantly high in humus media as compared to vermiculite and clay. Whatever, Harmony and Kariba also had a significantly high performance in vermiculite as compared to clay. In other words, Humus media had a significantly high performance as compared to vermiculite and clay.

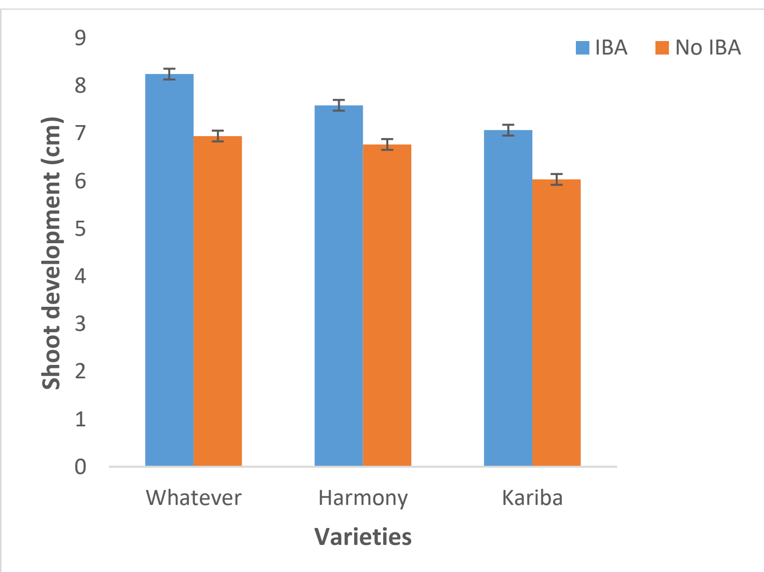

Fig 4.62 showing effect of IBA on different varieties.

Whatever with IBA had a significantly high performance as compared to Whatever without IBA. Harmony with IBA had a significantly high performance as compared to Harmony without IBA. Kariba with IBA had a significantly high performance as compared to Kariba without IBA.

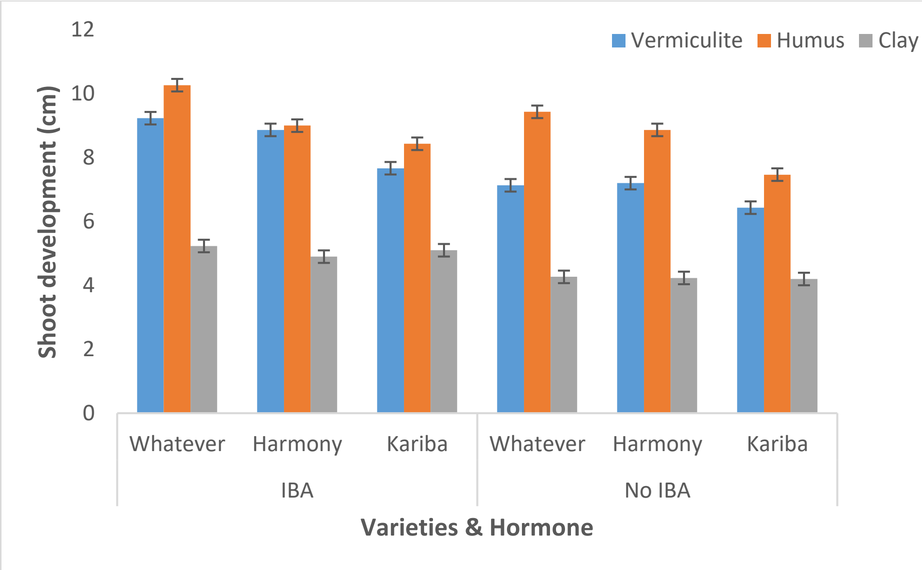

Fig 4.63 showing impact of media-variety-hormone interaction on shoot development.

Whatever, Harmony and Kariba performed significantly higher in vermiculite with IBA than in vermiculite without IBA. Whatever, Harmony and Kariba also performed significantly higher in clay with IBA than in clay without IBA. Whatever and Kariba also performed significantly higher in humus with IBA than in humus without IBA. There was no significant performance difference between Harmony in humus with IBA and Harmony in humus without IBA.

4.2.2 Shoot development at 28 days.

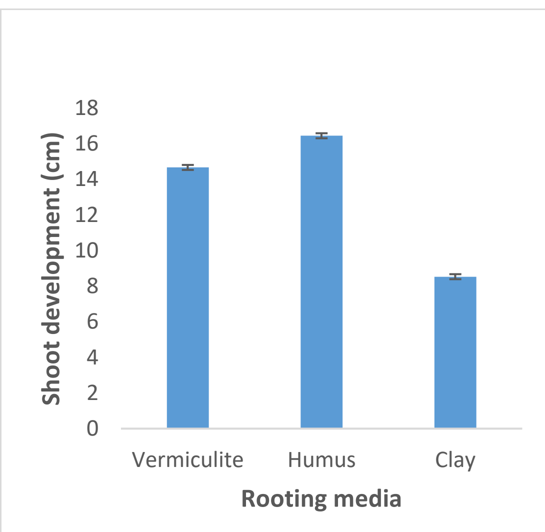

Fig 4.64 showing performance of rooting media on shoot development.

The above figure shows that, humus had a significantly higher performance as compared to vermiculite and clay. Vermiculite had a significantly high performance as compared to clay.

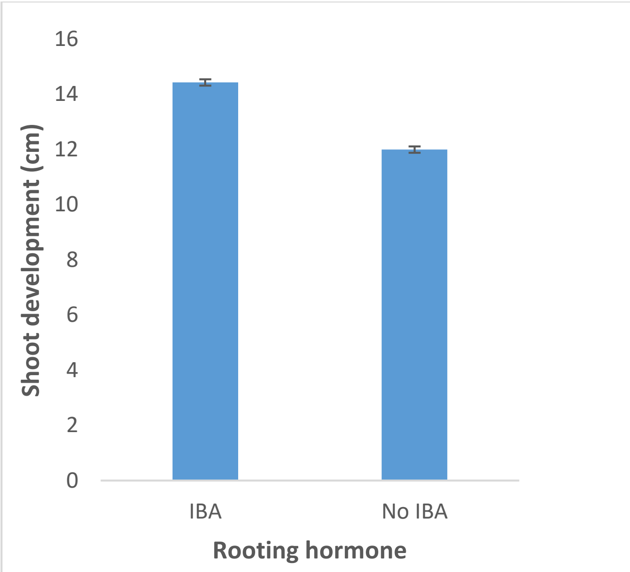

Fig 4.65 showing performance of IBA on shoot development.

Treatments with IBA had a significantly higher performance than treatments without IBA, as shown in figure 4.64 above.

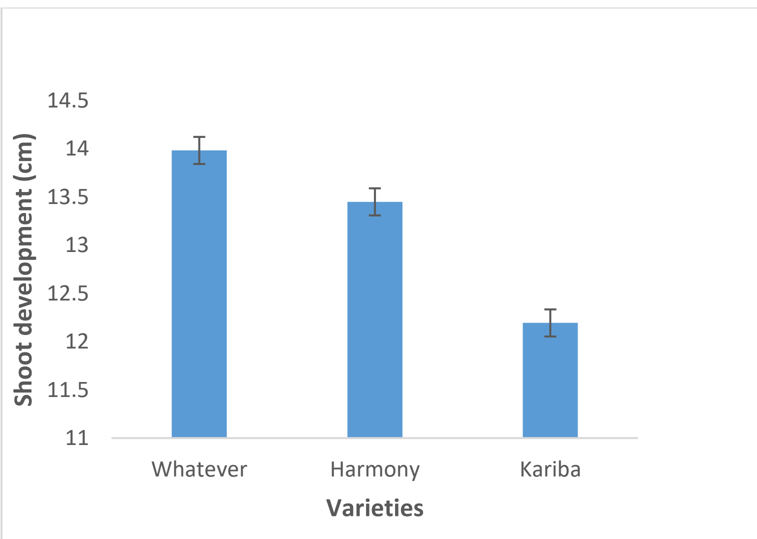

Fig 4.66 showing shoot development of the three roses varieties.

As illustrated in figure 4.66, Whatever had a significantly high performance than Harmony and Kariba. Harmony had a significantly high performance over Kariba.

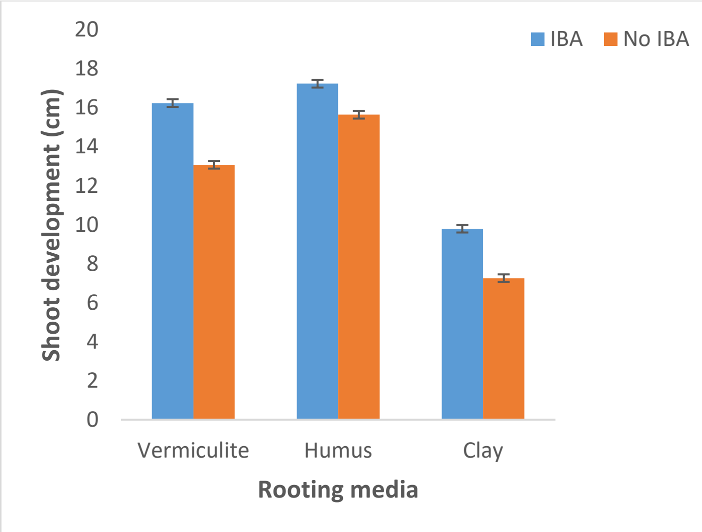

Fig 4.67 showing the impact of rooting media-hormone interaction on shoot development.

As shown in figure 4.67, vermiculite with IBA had a significantly high performance over vermiculite without IBA. Humus with IBA had a significantly high performance over humus without IBA. Clay with IBA had a significantly high performance over clay without IBA.

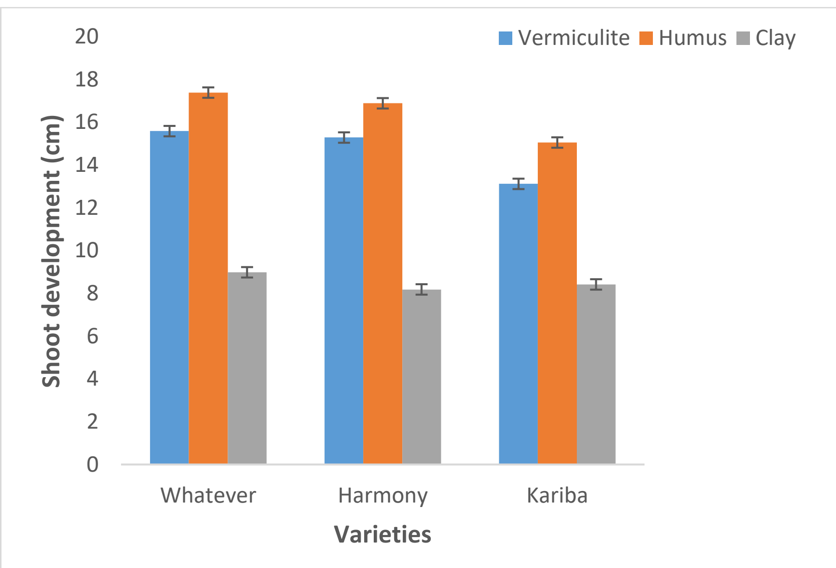

Fig 4.68 showing shoot development as impacted by rooting media-variety interaction.

Figure 4.68 above shows that, Whatever, Harmony and Kariba performed significantly high in humus media as compared to vermiculite and clay. Whatever, Harmony and Kariba also had a significantly high performance in vermiculite as compared to clay. In other words, Humus media had a significantly high performance as compared to vermiculite and clay.

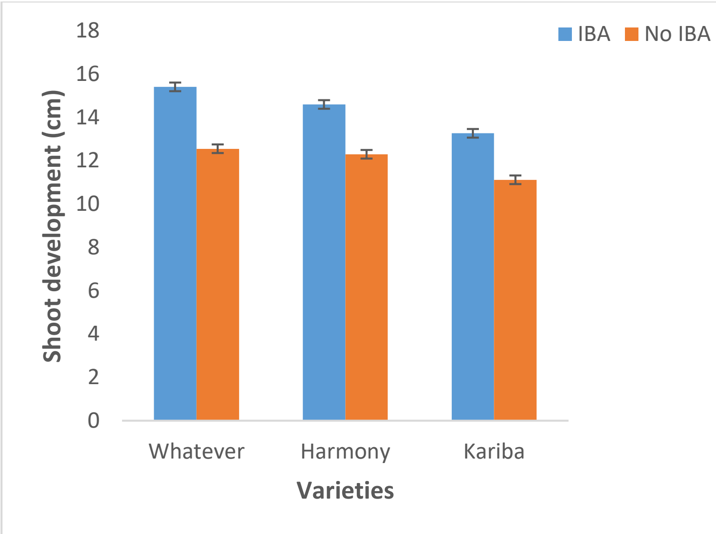

Fig 4.69 showing effect of IBA on different varieties on day 28.

Whatever with IBA had a significantly high performance as compared to Whatever without IBA. Harmony with IBA had a significantly high performance as compared to Harmony without IBA. Kariba with IBA had a significantly high performance as compared to Kariba without IBA.

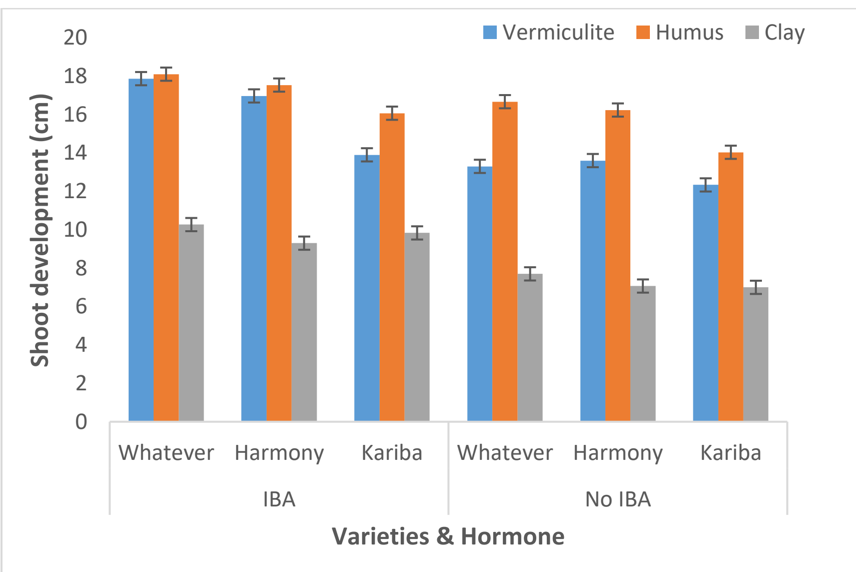

Fig 4.70 showing impact of media-variety-hormone interaction on shoot development.

Whatever, Harmony and Kariba performed significantly higher in vermiculite with IBA than in vermiculite without IBA. Whatever, Harmony and Kariba also performed significantly higher in clay with IBA than in clay without IBA. Whatever, Harmony and Kariba also performed significantly higher in humus with IBA than in humus without IBA.

CHAPTER 5

DISCUSSION

5.1 Effects of Indole 3-Butric Acid on root regeneration and development, and shoot development.

Indole 3-Butyric acid (IBA) is a good source of auxins and when applied exogenously, it has a variety of different effects on plant growth and development, but the compound is still mainly used for the induction of adventitious roots (Ludwig-Muller, 2000). Auxins are a class of phytohormones which are involved in many aspects of growth and development of plants (Ludwig-Muller, 2000). IBA has been the subject of many experiments mostly involving trial and error studies of different concentrations, formulations, additives and treatment durations to achieve optimum rooting for the plant species in question. According to Ludwig-Muller (2000), many researchers suggested that IBA's root development stimulating effect is closely associated with its induction of ethylene biosynthesis.

In addition, root initiation incurs regulation from endogenous auxins and carbohydrates stored in the stem cuttings, and various elements react with each other to promote rooting ability (Davies, 2010). In this experiment IBA promoted fast root development and growth in all the treatments it was applied. The presented results correspond with other research conducted by Susaj et al. (2012), who reported that rose cultivars Christopher Columbus and Vay Vicend treated with the IBA (1000 ppm) increased the shoot length, number of shoots, and other growth parameters. According to a research by Mohammed et al (2024), applying the IBA on rose cuttings improved root traits and length compared with the control treatments. In this experiment, the fastest root initiation time in IBA treatments was visible at 7 days, which opposes a result from a research by Mohammed et al (2024), where root initiation was visible after 2–4 weeks from treatment.

Moreover, in this experiment, an interaction of rooting hormone with rooting media presented a statistically significant effect on root development of grafted hybrid rose ($p<0.001$). This means that the impact of IBA was also media dependent. A significantly higher rooting performance was observed in vermiculite + coco-peat + calcium nitrate media and IBA was less effective in clay media, after 21 days from treatment (Fig 4.52). This correspond with research findings by Abdel-Rahman (2020), which states that, the combined treatment of 100 ppm IBA and vermiculite substrate significantly improved the rooting percentage, root and growth measurements of middle and basal cuttings as well as gave the highest C/N ratio in basal cutting tissues compared to the same cutting types combined with the other rooting media.

In this research, the type of cultivar had no significant effect on the performance of Indole Butyric acid ($p=725$), as shown in Fig 4.53. This is because the same rootstock of Natal Briar was used in grafting seedlings for all the three varieties therefore, its respond to IBA treatment can be similar. Other environmental factors may be the causes of the slight differences observed. The optimal IBA concentration to promote adventitious root development can vary between species, the cutting type, and/or the age of the donor plant (Inoue, 2023).

Furthermore, IBA had a significant effect ($p<0.001$) on the sprouting of grafted Rosa x hybrida, with the treatments treated with the hormone exhibiting a significantly higher sprouting rate and stem length than treatments without IBA. Application of rooting hormones to plant cuttings under nursery, is found to be the easiest way to enhance root and shoot growth, especially auxin derivatives that have a greater impact (Kakade et al, 2024). In this experiment, the performance of IBA in enhancing shoot development was also media dependent, with hormone-humus combination recording a significantly high performance. This might be attributed to the presence of humic substances in humus. Humic substances enhance essential nutrient supply and assimilation of atmospheric carbon dioxide due to increasing biomass yield (Tiwari et al, 2023). This is an additional advantage for humus.

5.2 Performance of different media in enhancing root and shoot development.

According to Saini et al (2022), the type of medium used is also critical to the rooting process since no single medium fulfills all the requirements of the different plant species, therefore, different combinations can be developed. In this experiment, rooting media had a significant effect on root development of grafted roses. It recorded significant level of difference ($p<0.001$) on the first week of root initiation and on the last days of root initiation, as indicated on Fig 4.1 and Fig 4.49. Humus showed the best performance followed by vermiculite + coco-peat + calcium nitrate media. Clay had a poor performance. Choi et al (2000) suggested that, such results might be attributed to the differences in water holding capacity, nutrient content and porosity of the rooting media composition.

The humus that was used in this experiment was 90% decomposed rose plant residues. There was a probability of having a high C:N ratio, accumulated auxins, optimum bulk density, good aeration, good water holding capacity, and most importantly, humic substances in that humus. Humic substances have oxygen, nitrogen, and sulphur-containing functional groups that allow them to make stable complexes in the soil with metal micronutrients, such as Iron, to maintain micronutrients in their available forms (Weisser et al, 2024). Studies in pepper and cucumber were reported to have an increased uptake of N, P, K, Ca, and Mg, after application of humic acids in field conditions (Cimrin et al, 2010 & El-Nemr et al, 2012). However, with humus having such abilities, it matches the result of this experiment where humus surpassed other used media in enhancing root and shoot development (Fig 4.56 & Fig 4.63).

A good performance in root and shoot development was also observed in vermiculite + coco-peat + calcium nitrate media. This media formulation comprised of two different media types (vermiculite and coco-peat) and one can cover the weakness of the other. Vermiculite and coco-peat are types of soil-less media that can provide specific benefits, such as improved aeration, moisture retention, and nutrient availability, which can influence root formation and overall plant health (Danso, 2024). Vermiculite naturally hosts a more diverse microbial community and coconut peat (coco-peat) maintains higher bacterial diversity and richness compared to vermiculite, harboring more beneficial bacteria and fungi, resulting in a more complex microbial network (Yan et al, 2024). This media formulation showed its ability to facilitate root development even without the application of rooting hormones. This might be attributed to the good qualities of the two, for example, vermiculite, which is a phyllosilicate mineral formed from the hydrothermal alteration of mica minerals such as biotite and phlogopite, and is of lightweight and resistant to heat decomposition (Addison, 1995). It also has a lower bulk density, conductivity, and specific surface area, but higher total porosity and cation exchange capacity, richer in calcium and sulfur, and demonstrates greater adsorption capacities for NH_4^+, NO_3^-, PO_4^{3-}, and K^+ (Tang et al, 2023). According to Yan (2024) the scarcity of organic nutrients in these substrates (soil-less media) limits plant growth and the colonization of roots by potential biocontrol agents, necessitating the addition of external fertilizers for nutrient adjustment. In this experiment, calcium nitrate was added. The presence of calcium in the root-soil system enhances the absorption and transport of nutrients to the stems, ultimately resulting in better and stronger growth of roses (Khosravi et al, 2024). Calcium nitrate also plays a crucial role in regulating crucial growth processes, and can affect the rate at which cells grow and divide.

Clay obtained from anthill had a poor performance as a rooting media, in enhancing root and shoot development, according to this research. This is attributed to the physical and physical properties of clay soil that makes it a poor rooting media if used alone. Clay particles are closely packed together and appear dense, hence, a higher bulk density. High bulk density soils inhibit root growth through reduced pore connectivity and available space to accommodate the displacement of soil particles as the root apex moves through the soil matrix (Valentine et al, 2012).

In this research, short and thicker roots were observed in treatments with clay as media. This may be due to production of ethylene by the plant. Ethylene may be an important signal in response to strong soils by causing radial thickening and slowing root elongation (Schneider et al, 2021). Ethylene diffusion is reduced in compacted soils and therefore accumulates near root tissues, which triggers a signaling cascade to stop root growth (Pandey et al., 2021). The outcome of this experiment on clay performance opposes a research by Imade et al (2024) which states that Pseudomonas aeruginosa, Klebsiella pneumoniae, and Bacillus sp. isolated from the anthill clay soil demonstrated plant growth promoting (PGP) characteristics including Indole 3-Acetic Acid production (auxin) and nitrogen fixation. Poor root respiration, is also another factor associated with clay soils, that contributed to poor shoot development.

5.3 Performance of different cultivars.

In this experiment, there was no significant difference in terms of root development performance among the three cultivars ($p>0.05$). This is because, one type of rootstock (Natal Briar) was used in the grafting of the three varieties therefore, and it couldn’t show significant rooting variations. Significant variations were seen on shoot development ($p<0.001$) where variety Whatever performed much better followed by Harmony and then Kariba (Fig 4.58 and Fig 4.65). Slight differences in root development and significant differences in shoot development might be attributed to the rootstock-scion relationship. Some varieties may take to time symbiotically bond with the rootstock in use hence, slow growth rate. Rootstock-scion relationship is also affected by the prevailing environmental conditions (Kwon et al, 2022). In this experiment, it can be concluded that Rosa x spp. Kariba and Natal Briar relationship did not favor the conditions maintained in the propagation house used leading to a slower shoot growth. This corresponds with a research by Kwon et al (2022) which revealed that, the effectiveness of grafting depends on the type of the scion and rootstock used. Nevertheless, there is still insufficient information on the mechanism behind these differences due to the characteristics of scions and rootstocks in relation to environmental conditions such as temperature and light intensity according to the season.

CHAPTER 6

6.1 CONCLUSION

During this study, it was observed that, decomposed rose residues (humus) can be successfully used as a good rooting media in the propagation of Rosa X Hybrida. It can promote root initiation, root growth, and help produce healthy shoots. Humus media can perform well even without the addition of rooting hormones such as Indole 3-Butyric Acid and Indole 3-Acetic acid, and synthetic fertilizers such as Calcium nitrate, making it a cost-effective and environmentally friendly rose propagation approach. A formulated media of vermiculite + coco-peat + calcium nitrate also showed good results on all varieties even without rooting hormones added. Humus and Vermiculite + coco-peat + calcium nitrate media are affordable hence they can be used by small holder farmers that lack enough funds to purchase rooting hormones.

The study also showed that there is logic in the application of Indole butyric acid in rooting media but it can depend on the type of media being used, the farmer’s capital status, and the time needed to complete the production cycle in order to meet market demands. Clay soil obtained from anthill exhibited poor results in both rooting and shooting of Rosa x hybrid. Some seedlings in the clay media even rotted on their rooting sections. Clay soil media took much time to initiate roots and shoots therefore, can delay production leading to economic losses due to market inconveniences.

6.2 RECOMMENDATIONS

Based on the results of this research, the first important recommendation is that, both large and small holder farmers who want venture into rose production, should be given access to useful information on the production of the crop so as to promote and restore its production levels, especially in Zimbabwe. This will boost the nation’s exports to fetch more revenue on international markets. Policymakers should also promote policies that support research, development, and adoption of sustainable and cost-effective ways of producing quality roses.

Secondly, for farmers to improve production efficiency, they should know good propagation skills that are cost-effective and useful. A farmer should know right time and situations that require application of rooting hormones and synthetic fertilizers. For instance, one can choose to utilize the fastness of humus and vermiculite +coco-peat + calcium nitrate with Indole butyric acid, to propagate and produce *Rosa x hybrida.* Whatever, when it is highly on demand on the market.

I also recommend that, using natural rooting media and organic derivatives is the safest way to preserve our environment therefore, more emphasis and research should be put on how to successfully use rooting media such as humus (organic matter), field soil and clay, which are eco-friendly. Humus and clay media taken from outside should be treated for dangerous microbes and pests such as termites and moths to avoid pest attack to plants under propagation. Furthermore, I recommend that researchers should also dig deep find methods that can be used to improve clay soil as a rooting media, as it is freely available.

REFERENCES

Abdel-Rahman, S. S. (2020). Influence of rooting media and indole-3-butyric acid (IBA) concentration on rooting and growth of different types of Conocarpus erectus L. stem cuttings. Scientific Journal of Flowers and Ornamental Plants, 7(3), 199-219.

Addison, J. (1955). Vermiculite: A review of the mineralogy and health effects of vermiculite exploitation. Regul. Toxicol. Pharmacol., 21, 397–405.

Agrawal, R. K., Tripathi, M. P., Verma, A., Sharma, G. L., & Khalkho, D. (2021). Effect on combinations of growing media for cultivation of horticultural crops in troughs, grow bag and pots: A review. IJCS, 9(1), 1545-1548.

Akladious, S. A., & Mohamed, H. I. (2018). Ameliorative effects of calcium nitrate and humic acid on the growth, yield component and biochemical attribute of pepper (Capsicum annuum) plants grown under salt stress. Scientia Horticulturae, 236, 244-250.

Aluvihara, S., Kalpage, C., & Bandaranayake, P. (2020). The elementary characterization of anthill clay for composite materials and industrial developments.

Bhagat, A. A., Badgujar, C. D., SS Bhosale, S. S., & Supe, V. S., (2019). An economics analysis for export of fresh cut rose flowers from India. Journal of Pharmacognosy and Phytochemistry 2019; SP2: 291-298

Bundela, R., & Fatmi, U. (2024). Evaluation of Different Hybrid Tea Roses (Rosa x hybrida) under Prayagraj Agro-climatic Conditions. Journal of Experimental Agriculture International, 46(6), 715-722.

Burch, J., Fluvià, M., Rigall, R., Saló, A., & Alcalde, G. (2019). Free or paid: the uses of Roses Citadel (Catalonia). Journal of Cultural Heritage Management and Sustainable Development, 9(1), 111-120.

Çancı, M. B., & Kılıç, M. (2020). Treatment of Rose Processing Wastewater By Sunlight/TiO2 Photocatalysis Process. Bilge International Journal of Science and Technology Research, 4(1), 1-6.

Choi, B. J., Sang, C. K., Choi, E. J., & Noh, S. A. (2000). Effect of rooting media on rooting and root growth of rose cuttings. Horticultural Science & Technology, 18(6), 819-822.

Çimrin, K.M.; Türkmen, Ö; Turan, M.; Tuncer, B. (2010). Phosphorus and humic acid application alleviate salinity stress of pepper seedling. Afr. J. Biotechnol, 9, 5845–5851.

Cotrufo, M. F., & Lavallee, J. M. (2022). Soil organic matter formation, persistence, and functioning: A synthesis of current understanding to inform its conservation and regeneration. Advances in agronomy, 172, 1-66.

Danso, W. (2024). Impact of stem cutting types and soilless media on vegetative and rooting growth. The American Journal of Horticulture and Floriculture Research, 6(08), 7-11.

Davies, P. J. (2010). Regulatory factors in hormone action: Level, location and signal transduction. In Plant hormones: Biosynthesis, signal transduction, action! (pp. 16-35). Dordrecht: Springer Netherlands.

Davies PJ. 2013. Plant hormones: physiology, biochemistry and molecular biology. Dordrecht: Springer Science & Business Management.

Doğan, E., Kazaz, S., Kiliç, T., Dursun, H., Ünsal, T. H., & Uran, M. (2020). A research on determination of the performance Rosa damascena Mill. as pollen sources in rose breeding by hybridization.

El-Nemr, M.; El-Desuki, M.; El-Bassiony, A.; Fawzy, Z. (2012). Response of growth and yield of cucumber plants (Cucumis sativus L.) to different foliar applications of humic acid and bio-stimulators. Aust. J. Basic Appl. Sci., 6, 630–637.

Guaita-Pradas, I., Rodríguez-Mañay, L. O., & Marques-Perez, I. (2023). Competitiveness of Ecuador's flower industry in the global market in the period 2016–2020. Sustainability, 15(7), 5821.

Heri, S. (2000). The growth and development of the horticultural sector in Zimbabwe. In UNCTAD Conference. Geneva, Switzerland (pp. 2-32).

Imade, E. E., Enagbonma, B. J., Ediagbonya, D. I., Molokwu, E. U., Nwodo, C., Ejuwehwe, E. O., & Udokwu, C. S. (2024). Profiling the biocontrol agents, nitrogen-fixing bacteria, and indole acetic acid-producing bacteria in anthill soil. Proceedings of the Nigerian Academy of Science, 17(1s), 111-121.

Inoue, S., Ilogu, C., & Sobze, J. M. (2023). Effects of indole-3-butyric acid and age of stem cuttings on root morphology, growth, and survival of Cornus sericea. Journal of Forestry Research, 34(2), 433-440.

Jeffrey, M. (2020). Flower growers hold up Zimbabwe's falling economy. Eve of Micro, Small, and Medium-sized Enterprises Day. Anadolu Agency

Jing, H., Tan, X., Xu, J., Zhou, G., & Li, G. (2011). Cinnamaldehyde prolongs the vase life of cut rose through alleviating oxidative stress. European Journal of Horticultural Science, 76(2), 69.

Kakade, V. D., Nangare, D. D., Chavan, S. B., Babar, R. R., Morade, A., Jadhav, S., & Jinger, D. (2024). Influence of indole butyric acid on root and shoot growth in dragon fruit (Selenicereus undatus) stem cuttings.

Kentelky, E., Székely-Varga, Z., & Balla, G. (2023). Propagation of rose varieties by cuttings under the effect of different rooting hormones. Acta Universitatis Sapientiae Agriculture and Environment, 15(1), 98–109. https://doi.org/10.2478/ausae-2023-0009

Khadr, A., Wang, G. L., Wang, Y. H., Zhang, R. R., Wang, X. R., Xu, Z. S., ... & Xiong, A. S. (2020). Effects of auxin (indole-3-butyric acid) on growth characteristics, lignification, and expression profiles of genes involved in lignin biosynthesis in carrot taproot. PeerJ, 8, e10492.

Khosravi, S., Tehranifar, A., Selahvarzi, Y., Khoshgoftarmanesh, A. H., & Cheheltanan, L. (2024). The impact of foliar application of calcium nitrate fertilizer on the quantity, quality, and post-harvest life of two varieties of roses (Rosa hybrida L.) in a soilless cultivation system. Journal of Plant Nutrition and Fertilizers.

Kılıç T. 2023. Identifying successful combinations by fertility index in old garden roses and hybrid tea roses crosses. PeerJ 11:e15526 https://doi.org/10.7717/peerj.15526

Kumar, M. S., Ponnuswami, V., Jawaharlal, M. and Ramesh Kumar, A. 2012. Effect of plant growth regulators on growth, yield and exportable quality of cut roses. The Bioscan. 7(4): 733-738

Kumar, S., Malik, A., Yadav, R., & Yadav, G. (2019). Role of different rooting media and auxins for rooting in floricultural crops: A review. International Journal of Chemical Studies, 7(2), 1778-1783.

Kumarasinghe, H. K. M. S., Subasinghe, S., & Ransimala, D. (2016). Effect of coco peat particle size for the optimum growth of nursery plant of greenhouse vegetables. Tropical Agricultural Research and Extension, 18(1), 51. https://doi.org/10.4038/tare.v18i1.5324

Kumari, N., & Mohan, C. (2021). Basics of clay minerals and their characteristic properties. Clay Clay Miner, 24(1).

Kwon, O. H., & Choi, H. G. (2022). Yield, flower quality, and photo-physiological responses of cut rose flowers grafted onto three different rootstocks in summer season. Agronomy, 12(6), 1468.

Leus, Leen & Laere, Katrijn & Riek, Jan & Huylenbroeck, Johan. (2018). Rose. 10.1007/978-3-319-90698-0_27.

Ludwig-Müller, J. (2000). Indole-3-butyric acid in plant growth and development. Plant Growth Regulation, 32, 219-230.

Mahendra Dev, S. (2014). Small farmers in India: Challenges and opportunities.

Makwana, R. J., Alka Singh and Neelima, P. 2015. Effect of cold storage techniques on flower quality and vase life of Rose var SunKing.The Bioscan 10(1): 225-22

Meng, J., Fougère-Danezan, M., Zhang, L. B., Li, D. Z., & Yi, T. S. (2011). Untangling the hybrid origin of the Chinese tea roses: evidence from DNA sequences of single-copy nuclear and chloroplast genes. Plant systematics and evolution, 297, 157-170.

Mohammed, I., Karrar, H., Al-Taey, D. K. A., Li, G., Ren, Y., & Alsaffar, M. F. (2024). Response of rose stem cuttings to Indole-3-Butyric acid for root formation and growth traits. SABRAO journal of breeding and genetics, 56(3), 1187-1198.

Nesse, William D. (2000). Introduction to mineralogy. New York: Oxford University Press. ISBN 9780195106916.

Nybom, H. (2009). Introduction to rosa. Genetics and Genomics of Rosaceae, 339-351.

Pandey, B.K., Huang, G., Bhosale, R., Hartman, S., Sturrock, C.J., Jose, L. et al. (2021) Plant roots sense soil compaction through restricted ethylene diffusion. Science, 371, 276–280.

Popkin, G. (2021). A soil-science revolution upends plans to fight climate change. Quanta Magazine.

Poonam Saini, Goyal, R. K., Pooja & Reetika. (2022). Effect of different rooting media, planting time and IBA treatment on shoot characters of pomegranate cuttings under open field conditions. The Pharma Innovation Journal 2022; SP-11(8): 157-165.

Pourghorban, M., Khaghani, S., Azadi, P., Mirzakhani, A., & Changizi, M. (2019). Propagation of Rosa hybrida L. cv. Dolce Vita by stenting and stem cutting methods in response to different concentrations of IBA. Advances in Horticultural science, 33(1), 105-112.

Rajan, R. P., & Singh, G. (2021). A review on the use of organic rooting substances for propagation of horticulture crops. Plant Archives, 21(1), 685-692.

roelof@luxaflorroses.com / www.luxaflorroses.com

Rossa, Ü. B., Winckler, P. R., Winckler Filho, P. R., Westphalen, D. J., & Gaspar, R. G. B. (2019). Cuttings of Euphorbia phosphorea Mart and Euphorbia enterophora Drake at different concentrations of indole-butyric acid and analysis of economic viability. Ornamental Horticulture, 25(3), 314-323.

Shaafi, B., Kahrizi, D., Zebarjadi, A., & Azadi, P. (2022). The effects of nanosilver on bacterial contamination and increase durability cultivars of Rosa hybrida L. through of stenting method. Cellular and Molecular Biology, 68(3), 179-188.

Shohayeb, M., Arida, H., Abdel-Hameed, E. S. S., & Bazaid, S. (2015). Effects of Macro-and Microelements in Soil of Rose Farms in Taif on Essential Oil Production by Rosa damascena Mill. Journal of Chemistry, 2015(1), 935235.

Susaj, E., Susaj, L., & Kallço, I. (2012). Effect of different NAA and IBA concentrations on rooting of vegetative cuttings of two rose cultivars.

Tang, Y.; Shen, Y.; Feng, H.; Wu, H.; Mao, R.; Ai, W.; Wu, Z. (2023). Study on primary physicochemical characteristics and nutrient adsorption of four plant cultivation substrates. Life Sci. Space Res. 36, 78–85.

Tiwari, J., Ramanathan, A. L., Bauddh, K., & Korstad, J. (2023). Humic substances: Structure, function and benefits for agroecosystems—A review. Pedosphere, 33(2), 237-249.

Valentine, T.A., Hallett, P.D., Binnie, K., Young, M.W., Squire, G.R., Hawes, C. et al. (2012) Soil strength and macropore volume limit root elongation rates in many UK agricultural soils. Annals of Botany, 110(2), 259–270.

Vanhees, D., Schneider, H., Sidhu, J., Loades, K., Bengough, A., Bennett, M. et al. (2021) Soil penetration by maize roots is negatively related to ethylene-induced thickening. Plant, Cell & Environment.

Voltr, V., Menšík, L., Hlisnikovský, L., Hruška, M., Pokorný, E., & Pospíšilová, L. (2021). The soil organic matter in connection with soil properties and soil inputs. Agronomy, 11(4), 779.

Wang, L., Wang, X., Yin, J., & Wang, C. (2016). Insights into the physicochemical characteristics from vermiculite to silica nanosheets. Applied Clay Science, 132, 17-23.

Wang, W., & Wang, A. (2019). Vermiculite nanomaterials: Structure, properties, and potential applications. In Nanomaterials from Clay Minerals (pp. 415-484). Elsevier.

Weisser, M., Mattner, S. W., Southam-Rogers, L., Hepworth, G., & Arioli, T. (2023). Effect of a Fortified Biostimulant Extract on Tomato Plant Productivity, Physiology, and Growing Media Properties. Plants, 13(1), 4.

LIST OF APPENDICES

Analysis of variance

Variate: **Root development at Day_7**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.01370	0.00685	0.35	
Block.*Units* stratum					
Media	2	4.16704	2.08352	105.27	<.001
hormone	1	0.80667	0.80667	40.76	<.001
variety	2	0.01037	0.00519	0.26	0.771
Media.hormone	2	0.75444	0.37722	19.06	<.001
Media.variety	4	0.09519	0.02380	1.20	0.328
hormone.variety	2	0.01333	0.00667	0.34	0.716
Media.hormone.variety	4	0.00556	0.00139	0.07	0.991
Residual	34	0.67296	0.01979		
Total	53	6.53926			

Variate: **Root development at Day_9**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.08444	0.04222	1.03	
Block.*Units* stratum					
Media	2	11.10111	5.55056	135.88	<.001
hormone	1	1.74241	1.74241	42.65	<.001
variety	2	0.25444	0.12722	3.11	0.057
Media.hormone	2	2.03815	1.01907	24.95	<.001
Media.variety	4	0.27778	0.06944	1.70	0.173
hormone.variety	2	0.03815	0.01907	0.47	0.631
Media.hormone.variety	4	0.08296	0.02074	0.51	0.730
Residual	34	1.38889	0.04085		
Total	53	17.00833			

Variate: **Root development at Day_11**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.06778	0.03389	0.78	
Block.*Units* stratum					
Media	2	20.84333	10.42167	240.68	<.001
hormone	1	2.44907	2.44907	56.56	<.001
variety	2	0.07000	0.03500	0.81	0.454
Media.hormone	2	2.58259	1.29130	29.82	<.001
Media.variety	4	0.58667	0.14667	3.39	0.020
hormone.variety	2	0.08037	0.04019	0.93	0.405
Media.hormone.variety	4	0.15630	0.03907	0.90	0.473
Residual	34	1.47222	0.04330		
Total	53	28.30833			

Variate: **Root development at Day_13**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.04148	0.02074	0.57	
Block.*Units* stratum					
Media	2	31.89926	15.94963	437.85	<.001
hormone	1	1.92667	1.92667	52.89	<.001
variety	2	0.05148	0.02574	0.71	0.500
Media.hormone	2	1.99111	0.99556	27.33	<.001
Media.variety	4	1.46407	0.36602	10.05	<.001
hormone.variety	2	0.14111	0.07056	1.94	0.160
Media.hormone.variety	4	0.38778	0.09694	2.66	0.049
Residual	34	1.23852	0.03643		
Total	53	39.14148			

Variate: **Root development at Day_15**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.04148	0.02074	0.40	
Block.*Units* stratum					
Media	2	37.64926	18.82463	362.59	<.001
hormone	1	2.66667	2.66667	51.36	<.001
variety	2	0.37370	0.18685	3.60	0.038
Media.hormone	2	2.62333	1.31167	25.26	<.001
Media.variety	4	0.69296	0.17324	3.34	0.021
hormone.variety	2	0.15444	0.07722	1.49	0.240
Media.hormone.variety	4	0.31889	0.07972	1.54	0.214
Residual	34	1.76519	0.05192		
Total	53	46.28593			

Variate: **Root development at Day_17**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	20.24	10.12	0.97	
Block.*Units* stratum					
Media	2	105.44	52.72	5.03	0.012
hormone	1	2.41	2.41	0.23	0.635
variety	2	22.74	11.37	1.09	0.349
Media.hormone	2	42.62	21.31	2.03	0.146
Media.variety	4	38.25	9.56	0.91	0.468
hormone.variety	2	20.54	10.27	0.98	0.385
Media.hormone.variety	4	40.41	10.10	0.96	0.440
Residual	34	356.16	10.48		
Total	53	648.81			

Variate: **Root development at Day_19**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.10037	0.05019	0.80	
Block.*Units* stratum					
Media	2	56.75148	28.37574	452.32	<.001
hormone	1	5.10296	5.10296	81.34	<.001
variety	2	0.20481	0.10241	1.63	0.210
Media.hormone	2	4.39370	2.19685	35.02	<.001
Media.variety	4	0.27741	0.06935	1.11	0.370
hormone.variety	2	0.12704	0.06352	1.01	0.374
Media.hormone.variety	4	0.03963	0.00991	0.16	0.958
Residual	34	2.13296	0.06273		
Total	53	69.13037			

Variate: **Root development at Day_21**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.04148	0.02074	0.22	
Block.*Units* stratum					
Media	2	73.96926	36.98463	397.28	<.001
hormone	1	8.56019	8.56019	91.95	<.001
variety	2	0.31593	0.15796	1.70	0.198
Media.hormone	2	6.00704	3.00352	32.26	<.001
Media.variety	4	0.31074	0.07769	0.83	0.513
hormone.variety	2	0.06037	0.03019	0.32	0.725
Media.hormone.variety	4	0.29074	0.07269	0.78	0.546
Residual	34	3.16519	0.09309		
Total	53	92.72093			

Variate: **Shoot development at Day_21**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.5159	0.2580	2.23	
Block.*Units* stratum					
Media	2	174.3304	87.1652	753.96	<.001
hormone	1	14.9363	14.9363	129.20	<.001
variety	2	9.9515	4.9757	43.04	<.001
Media.hormone	2	2.6415	1.3207	11.42	<.001
Media.variety	4	5.5319	1.3830	11.96	<.001
hormone.variety	2	0.5159	0.2580	2.23	0.123
Media.hormone.variety	4	0.7230	0.1807	1.56	0.206
Residual	34	3.9307	0.1156		
Total	53	213.0770			

Variate: **Root development at Day_28**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.1848	0.0924	0.26	
Block.*Units* stratum					
Media	2	620.1837	310.0919	872.16	<.001
hormone	1	79.9350	79.9350	224.82	<.001
variety	2	30.3659	15.1830	42.70	<.001
Media.hormone	2	5.6844	2.8422	7.99	0.001
Media.variety	4	11.5141	2.8785	8.10	<.001
hormone.variety	2	1.2578	0.6289	1.77	0.186
Media.hormone.variety	4	6.3111	1.5778	4.44	0.005
Residual	34	12.0885	0.3555		
Total	53	767.5254			