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Effects of Different Growing Media on Propagation of Rose (*Rosa hybrida* L.) Stem Cuttings

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Abstract

Roses (*Rosa hybrida* L.) have been symbols of love, beauty, war, and politics. The rose is, according to fossil evidence, 35 million years old. In nature, the genus Rosa has some 150 species spread throughout the Northern Hemisphere, from Alaska to Mexico and including northern Africa. The experiment was conducted with the aim of making Swazi farmers consider ornamental farming as a means of generating income and also for sustaining the national economy by using the most effective and cheapest media available. Rose cuttings were rooted using sawdust, sand, garden soil and, cattle manure. A Randomized Complete Block Design (RBCD) was used in the experiment and treatments were replicated four times and each treatment consisted of twenty plants. There was a significant ($P < 0.05$) difference in shoot fresh mass of rose grown in different media. There was no significant ($P > 0.05$) difference in plant grown in sawdust and sand. The highest fresh mass (0.39g) was obtained in plants grown in the sand. Although cuttings propagated in garden soil did not root as vigorously as sand but there was no significance ($P > 0.05$) fresh mass and dry mass of roots when compared to garden soil and sawdust. It can be recommended to use the sand as growing medium for the rooting rose cuttings. Not only the sand can be used but also garden soil and sawdust has good qualities for growing plants but it is readily available and inexpensive for almost all economic classes in the country.

Keywords: *Rosa hybrida L.; Garden Soil; Sawdust; Sand; Cattle Manure*

Introduction

Background information

Roses (*Rosa hybrida* L.*)* have a long and colourful history. They have been symbols of love, beauty, war, and politics. The rose is, according to fossil evidence, 35 million years old. In nature, the genus *Rosa* has some 150 species spread throughout the Northern Hemisphere, from Alaska to Mexico and including northern Africa. Garden cultivation of roses began some 5,000 years ago, probably in China. During the Roman period of Roman Empire, roses were grown extensively in the Middle East. They were used as confetti at celebrations, for medicinal purposes, and as a source of perfume. Roman nobility established large public rose gardens in the south of Rome. After the fall of the Roman Empire, the popularity of roses seemed to rise and fall depending on gardening trends of the time [1].

During the fifteenth century, the rose was used as a symbol for the factions fighting to control England. The white roses symbolized York, and the red roses symbolized Lancaster, as a result, the conflict became known as the "War of the Roses".

Roses were in such high demand during the seventeenth century that royalty considered roses or rose water as legal tender, and they were often used as barter and for payments. Napoleon's wife Josephine established an extensive collection of roses at Chateau de Malmaison, an estate 11.3 km west of Paris in the 1800s [1]. This garden became the setting for Pierre Joseph Redoute's work as a botanical illustrator. In 1824, he completed his watercolor collection "Les Rose," which is still considered one of the finest records of botanical illustration [1].

It wasn't until the late eighteenth century that cultivated roses were introduced into Europe from China. Most modern-day roses can be traced back to this ancestry. These introductions were repeat bloomers, making them unusual and of great interest to hybridizers, setting the stage for breeding work with native roses to select for hardiness and a long bloom season. Many of these early efforts by plant breeders are of great interest to today's gardeners [2].

Roses are once again enjoying resurgence in popularity, specifically, shrub roses and old garden roses. Gardeners realize that these roses fit the lifestyle of today's gardeners who want roses that are not as demanding with regard to disease control, offer excellent floral quality, have excellent winter hardiness, and fit into shrub borders and perennial gardens without seeming out of place [3]. To be successful in growing roses in Midwest gardens, one needs to be aware of some basic considerations. Attention to plant selection, a basic knowledge of the wide array of classes available, basic culture information, and information about potential disease and insect problems will go a long way in making roses an enjoyable addition to the garden [1].

The rose is a type of flowering shrub. The flowers of the rose grow in many different colors, from the well-known red rose or yellow roses and sometimes white or purple roses [4]. Many roses have a strong, pleasant scent. Most roses have prickles (incorrectly called thorns) on their stems. Rose bushes are able to tolerate a wide variety of growing conditions. The fruit of the rose is called a hip. Some roses have decorative hips [2].

Problem statement

The major problems that slow down ornamental plant production could be related to propagation critically on the part of the media chosen [5]. Rose is propagated by stem cuttings. Economic production requires rooted cuttings to be available at the same time uniformly. Root formation and shooting is influenced by the growing media used considering how the importing of peat is relatively expensive thus developing an alternatively cheap and locally available growing media is desirable.

Objectives

General objective

The general objective is to promote horticultural production in Swaziland so as to increase farm income.

Specific objective

To determine the effects of sand, garden soil, sawdust, and cattle manure on the rooting of rose stem cuttings.

Justification

Due to heavy and intensive competition in the sugar industry and sugar cane being the major cash crop in Swaziland, it is without doubt that the farming sector needs to diversify into horticultural commodities like flowers, baby vegetables etc. The continuous improvement in living standards and economic growth indicate an expected increase in interest and demand for ornamental plants and recreational facilities [6]. The full potential of horticulture is yet to be exploited in Swaziland as currently the ornamental business is a small sector comprised of a few nurseries and garden center's here and there.

Literature of Review

Rose production

Botany of Rose

Rose is a woody perennial flowering plant of the genus *Rosa*, in the family Rosaceae, or the flower it bears. There are over a hundred species and thousands of cultivars. They form a group of plants that can be erect shrubs, climbing or trailing with stems that are often armed with sharp prickles. Flowers vary in size and shape and are usually large and showy, in colours ranging from white through yellows and reds. Most species are native to Asia, with smaller numbers native to Europe, North America, and north western Africa. Species, cultivars and hybrids are all widely grown for their beauty and often are fragrant. Roses have acquired cultural significance in many societies. Rose plants range in size from compact, miniature roses, to climbers that can reach seven meters in height. Different species hybridize easily, and this has been used in the development of the wide range of garden roses [1].

The leaves are borne alternately on the stem. In most species they are 5 - 15 cm long, pinnate, with (3 - 5 cm) leaflets and basal stipules; the leaflets usually have a serrated margin and often a few small prickles on the underside of the stem. Most roses are deciduous but a few (particularly from South East Asia) are evergreen or nearly so [2]. The flowers of most species have five petals, with the exception of Rosacea, which usually has only four. Each petal is divided into two distinct lobes and is usually white or pink, though in a few species yellow or red. Beneath the petals are five sepals (or in the case of some Rosacea, four). These may be long enough to be visible when viewed from above and appear as green points alternating with the rounded petals [3]. There are multiple superior ovaries that develop into achenes. Roses are insect-pollinated in nature. The aggregate fruit of the rose is a berry-like structure called a rose hip. Many of the domestic cultivars do not produce hips, as the flowers are so tightly petalled that they do not provide access for pollination. The hips of most species are red, but a few (e.g. *Rosa pimpinellifolia)* have dark purple to black hips. Each hip comprises an outer fleshy layer, the hypanthium, which contains 5 - 160 "seeds" (technically dry single-seeded fruits called achenes) embedded in a matrix of fine, but stiff, hairs. According to Hamrick [4], rose hips of some species, especially the dog rose (*Rosa canina*) and rugosa rose (*Rosa rugosa*), are very rich in vitamin C, among the richest sources of any plant. The hips are eaten by fruit-eating bird such as thrushes and waxwings, which then disperse the seeds in their droppings. Some birds, particularly finches, also eat the seeds. Rose thorns are actually prickles - out-growths of the epidermis. True thorns, as produced by e.g. Citrus or Pyracantha, are modified stems, which always originate at a node and which have nodes and internodes along the length of the thorn itself. Rose prickles are typically sickle-shaped hooks, which aid the rose in hanging onto other vegetation when growing over it. Some species such as *Rosa rugosa* and *Rosa pimpinellifolia* have densely packed straight prickles, probably an adaptation to reduce browsing by animals, but also possibly an adaptation to trap wind-blown sand and so reduce erosion and protect their roots (both of these species grow naturally on coastal sand dunes). Despite the presence of prickles, roses are frequently browsed by deer [2].

Uses

Roses are best known as ornamental plants grown for their flowers in the garden and sometimes in doors. They have been also used for commercial perfumery and commercial cut flower crops. Some are used as landscape plants, for hedging and for other utilitarian purposes such as game cover and slope stabilization. They also have minor medicinal uses. Sometimes rose petals are dried and packed so that you can use them for decoration or for scent. Roses can be seen very much in gardens. Sometimes they can be in vineyards as well. In a big vineyard, bush of roses are planted at the end of each row of vines [1]. As long as the roses stay healthy, the vine growers can see that their vines are healthy as well. This 'Tuscany Superb' rose cultivar was discovered in 1837. There are thousands of rose cultivars that people grow in gardens and on farms. The names used to describe the different types often refer to one species that is the main ancestor of that group, for example, Gallica roses are mostly descended from *Rosa gallica*. Other groups have several different species among their ancestors. Hybrid Tea roses, Floribunda roses, and English roses are the most common in gardens today. They are of so many colours like red, yellow, orange, pink, and purple and so on [2].

Propagation media

Farmers and nurseries use various seedling and potting media in the production of field transplants, container plants and greenhouse plants. Such media may contain a wide range of natural and synthetic materials. It is, therefore, of utmost importance to select the appropriate rooting media for the right plant [7].

Rooting media are the materials in which plants are rooted. Rooting media can comprise of one ingredient or a mixture of ingredients, with or without soil. Soil-less media have been long recognized as superior to soil based alternatives and generally peat moss based or, for certain plant species, tree bark based. The advantages of soil-less rooting media includes its consistency, uniformity, transportation efficiency and more suitable air and water relation which is optimal for plant growth [5].

Among the variety of rooting media available, peat moss is considered by professional growers and general gardeners as to be the best ingredient to include in rooting media or for soil amendment. Peat moss is unique and ideal rooting medium due to its homogeneous composition, high structural stability, capacity for retaining water and air. It contains cavities which enable it to hold air, water and nutrients in a balanced proportion. As a result of peat moss superior nature to other mediums, professional growers and garden retail consumers demand it. There is no close substitute for peat and its domination in the market continues to increase its retail price [5].

Most top soils do not have the qualities required to produce optimum plant growth, without good root growth the plant or cutting cannot absorb an adequate amount of water and fertilizer. Consequently, the plant may not be as vigorous or produced/develop as well rooted plant or cutting [8]. A good medium is one that has a continuous supply of air, moisture and nutrient element in a uniform proportion. Other media are mixed with other substances or properties that help reduce their cost such as sawdust, compost and topsoil for others. Regardless of this the uniformity and consistency of peat still stands out but the supply remains scarce with a heavy price tag for rural or general local farmers.

The choice of media chosen to root cuttings depends on the factors such as, availability of materials, size and type of container for growing. There is no best media to grow cuttings. Cuttings can be groomed even from properly homemade mixes so long as they can provide the prerequisite and ideal environment for root development and survival.

The growing medium which is also used as rooting medium is the material in which plants are developed. Media serves four major functions for plants: it holds water for plants use, provides the plant with nutrients and permits gaseous exchange to and from the roots and supports the plant. The other properties of mediums include organic matter, bulk density, and porosity, aeration, water holding capacity, pH and cation exchange capacity (CEC).

Rooting media consist of different components for media mixes such as mineral soil, sand, sphagnum peat moss, coir, vermiculite, pine bark, perlite, calcined clay and rock wool. Plain water can be used to propagate some cuttings depending on the species. Maloup., *et al.* [9] concluded that the use of soil as a growing medium in protected cultivation has started to face serious limitations. This is due to the fact that after years of cultivation, a decrease in soil fertility is observed, coupled with an increase in soil salinity, soil borne disease and pest which affect the productivity of high value crops. The medium should completely moist prior to inserting cuttings because if the medium is not moist then the cut surface may contact a dry pocket and have its own water absorbed away by the medium component this may lead to the death or wilting of the cutting [3].

A hole must be made in the medium and the cutting inserted deeply enough into the media to support itself. Specifically, the cutting should be stuck 0.6 - 1.3 cm deep. The most rapid rooting of cuttings occurs with night temperatures ranging between 15.6 - 17.2ºC. Normally, in intensive commercial production bottom heating of medium may be provided. Higher temperatures enhance growth but should not be excessively high as this does not allow photosynthesis to keep up with food breakdown in normal cell energy use [10].

The cutting should be placed in warm location that receives bright but indirect light and should avoid humidity build up. The moisture content of the rooting media must be monitored so as to not let the cuttings dry out. Normally, if the cuttings are to be later transplanted they are ready for transplant after 3 - 4 weeks and roots will fully appear after 18 - 20 days under ideal conditions [11].

For cuttings to thrive/survive and achieve maximum productivity, the root environment must at least constitute of the following criteria; an adequate supply of water, oxygen and nutrients and removal of carbon dioxide from the root environment [11]. The establishment of microbial population in the medium to decompose dead root tissue and root secretions. Insulation of roots against adverse fluctuations in temperature, the root temperature should not be below 15ºC. The media must media must act as an anchorage so that the roots can physically support the plant for example cucumbers need trellis.

Garden soil

Soil is the unconsolidated mineral material on the immediate surface of the earth that serves as a natural medium for the growth of land plants. The material has been influenced by genetic and environmental factors of parent material, climatic (moisture and temperature), topography and micro-organisms all acting over a period of time [12]. Heavy soils should not be used for rooting's: they tend to pack tightly which results in poor aeration and little or no root formation. They also must be thoroughly sterilized to prevent disease development. Top soils are also believed not to contain the best qualities for optimum root development [11].

Sand

Clean, coarse, construction grade sand can be used for rooting cuttings. The very fine sand should be avoided because it has poor aeration, which retards root formation. Sand in a growing mixture can make a difference. Coarse sands add air spaces to the potting mixture. Washed sand, neutral pH keeping in mind it's least expensive and ideal for plants which will later be moved [13].

Sawdust

Sawdust is commonly used in horticultural growing media and is usually composted before use. Because of the inherent differences in chemical properties between different woods, however, the suitability of sawdust as an organic growing media component is extremely variable. Mastalerz [14] stated that sawdust from incense-cedar, walnuts, or redwood is known to have direct phytotoxic effects. Stewart [15] reported that conifers grown on peaty soil types accumulate high levels of manganese, and that sawdust from such trees is phytotoxic if these materials are used for growing media. Worrall [16] investigated the properties of sawdust from several species of Eucalyptus and found that, even within this one genus, the presence of chemical toxins varied between tree species. Only sawdust from sawmills should be considered for growing media because other wood residues may contain preservatives or other harmful chemicals. Sawdust from coastal sawmills can contain high levels of salts, which can also be harmful to seedling growth (Gates, 1986). Obviously, sawdust should be chemically tested before it is used in growing media. Another potential problem is uniformity of particle size; particle size analysis of sawdust revealed a considerable amount of variability [17].

The species of tree from which sawdust is derived largely determines its quality and value for use in a growing media. Several sawdust's, such as walnut and non-composted redwood, are known to have direct phototoxic effects. However, the C:N of sawdust is such that it is not readily decomposed. The high cellulose and lignin content along with insufficient N supplies creates depletion problems which can severely restrict plant growth. However, supplemental applications of nitrogen can reduce this problem [15].

All hardwood sawdust, with the exception of jarrah, must be detoxified by decomposing before use in potting mixes. Compost are coarse sawdust, initially have good physical properties; finer sawdust need amending to improve aeration. A main problem experienced in nurseries with sawdust is variation in nitrogen drawdown between batches. Composts inclusion in potting mixes should be less due to their high nitrogen drawdown (Gates, 1986).

Cattle manure

Cattle manure is regarded as one of the best bulky organic materials commonly available as it adds worthwhile amount of organic matter in the soil. Cattle manure supplies useful amounts of organic matter which is about two-thirds that is supplied by the chicken manure [12]. Cattle manure is not rich in nitrogen as other manures; however the high ammonia levels can burn plants when fresh manure is directly applied. Composted cow manure on the other hand can provide numerous benefits to the garden. It is basically made of digested grass and grain. Cow dung is high in organic materials and rich in nutrients. In addition, it contains high levels of ammonia and potentially dangerous pathogens thus it's recommended that it is aged or composted prior before use [12].

Plant propagation

The propagation of plants draws back from the origin of agriculture and is old as civilization itself. Plant propagation is simply the increase in number of plants which can be achieved by two methods. The sowing of seeds to produce food crops is and was the earliest form of propagation and with this knowledge the era or revolution of agriculture begun. Where by man no longer was a gatherer nor hunter but a grower. There are number of ways to propagate plants commonly use of seed, tissue culture and by vegetative means. The choice of method depends on the crop being propagated. Usually floricultural crops and fruits are propagated by vegetative means. The propagation techniques applied in this modern age such as air layering, rooting of cuttings and grafting are ancient methods of increasing the number of plants [18].

The use of cuttings is the most common method of vegetative propagation. It involves placing a detached section of the parent plant, such as stem, root or leaf, under favourable conditions for rooting, shooting and flowering including general development depending on the study. This method of propagation is rapid and accurate. It is accepted and practiced by most commercial growers to increase their stock that will be true to type [19].

Konfranek (1992) suggested that the variable that enables cuttings to develop roots depends on the parent plant genetics, health and freshness of the cutting lastly the treatment application. Some physiological basis of rooting has been developed from studies on easy and difficult to root plants. The capacity for any plant material to root is affected by an inherent factors present in the cells of plants found in the leaves and buds.

Sexual reproduction

Sexual reproduction involves seeds and offspring of sexual propagation is a hybrid of the parent plants. The significance of sexual reproduction is combining of genetic material from two parents [20].

Asexual reproduction

Asexual reproduction is plant reproduction using vegetative parts of a plant such as leaves, stems or roots. New plants can be grown from parts of plants due to living cells contained in living plant parts. The cells have the ability to duplicate all plant part functions. The offspring resulting from asexual propagation are genetically identical or clones of the parent plant [20]. There are many methods of asexual propagation this may include separation, grafting, layering, and tissue culture. The most widely used method in floriculture industries are stem cuttings [20].

Weaver [21] recommended that in propagation cuttings be planted as soon they are harvested from the parent plant to reduce water loss from the cuttings. Quite a number of herbaceous plants are easily propagated by tissue culture. Plants like bananas and many ornamental plants are easily propagated through tissue culture. Tissue culture is a method used for vegetative propagation, employing a small piece of plant tissue, the explant grown in a sterile artificial medium supplying all mineral and organic nutrients, and enclosed in a vessel which is subjected to precisely controlled environment conditions.

Cuttings are the most common propagation of horticultural plants. Cuttings may be stem cuttings, leaf, root cuttings and shoot tip cuttings. Air layering is also used if cuttings are not successful in rooting. The rooting of leaf cuttings is very easy and successful if the leaf is succulent plant because the will be minimal water loss. The advantages of asexual reproduction include, production of plants with outstanding characteristics without the risk of losing the desired characteristics since recombination of genetics does not occur; production of genetically identical plants (clones); production of disease free plants and more rapid production of mature plants [20].

Rooting environment

One of the most important factors in successfully rooting cuttings is maintaining adequate moisture, both in the soil and in the form of humidity in the air. Place the cuttings in pots of moist sand or potting soil, then cover them with a plastic bag, mayonnaise jar or inverted two-liter soft drink bottle with the top cut off, creating a small tent or "greenhouse" to maintain high humidity around the cuttings. Roses root best in bright light. But when using the mini-greenhouse method, it's important to avoid overheating by giving some shade from hot, midday sun. Put the cuttings in bright shade, such as against the north wall of a building or under a tree, to allow rooting without too much heat build-up (Malcolm, 2014). Most cuttings root best in the spring or early summer, when the weather is warm but not miserably hot. Cuttings may be rooted at other times of the year, but it may take longer and a smaller percentage of them may take. A few types (such as the gallicas) may root more successfully in the winter.

Materials and Methods

Experimental site

The experiment was conducted from 09 November 2017 to 31 January 2018 in a lath house in the Horticulture Department Farm, Faculty of Agriculture, Luyengo Campus at the University of Swaziland. Luyengo is located in the Manzini region along the Middleveld agro-ecological zone with the altitude of 750 m above sea level, latitude of $26°4'S$ and $31°4'E$ [22].

Planting materials

The rose stem (semi-hard wood) cuttings of 20 cm long were obtained from rose plants around the Luyengo campus and were placed in a bucket filled with water during the course of harvesting which lasted for about three hours and thereafter they were dipped in a rooting hormone (seradix 2) and then inserted into a thoroughly wet rooting media. Cuttings were detached off leaves so as to prevent water loss through transpiration since they cannot be replaced due to absence of roots. Each cutting was stuck in 4-cm-diameter plastic bag, the bags were placed under benches covered with a clear polyethylene sheet to maintain high relative humidity. A total of 320 plastic bags were be used.

Experimental design

The experiment was laid out in a randomized complete block design (RCBD), each treatment replicated four times. The treatments were sand, sawdust, cattle manure and garden soil (control) (Table 1). Each treatment consisted of 20 cuttings.

Treatment code	Treatment description
1	Sawdust
2	Cattle manure
3	Sand
4	Garden soil

Table 1: *Description of treatments.*

Data collection

The data was collected starting eight weeks after potting (WAP), on a weekly basis for four weeks. This included parameters like number of roots, length of roots, number of leaves and length of leaves, fresh and dry mass of roots, fresh and dry mass of shoots. The samples were randomly picked from each treatment and 4 samples were selected per treatment.

Data analysis

Data collected was subjected to analysis of variance (ANOVA) using GEN-STAT statistical package [23]. Mean separation was done by the least significant figure (LSD) where significant differences were detected [24].

Results

Number of leaves

There were significant ($P < 0.05$) differences in number of leaves of roses between cuttings rooted in sand, cattle manure and sawdust (WAP 10). There was no significant ($P > 0.05$) difference in number of leaves between cuttings rooted in garden soil and sand (WAP 8, 9, 10 and 11) (Figure 1). At 10 WAP, the highest number of leaves (10.2) was obtained in cuttings rooted in the sand and the lowest number of leaves (0.3) was obtained in cuttings rooted using cattle manure. The second best results were obtained from cuttings rooted in garden soil (Figure 1).

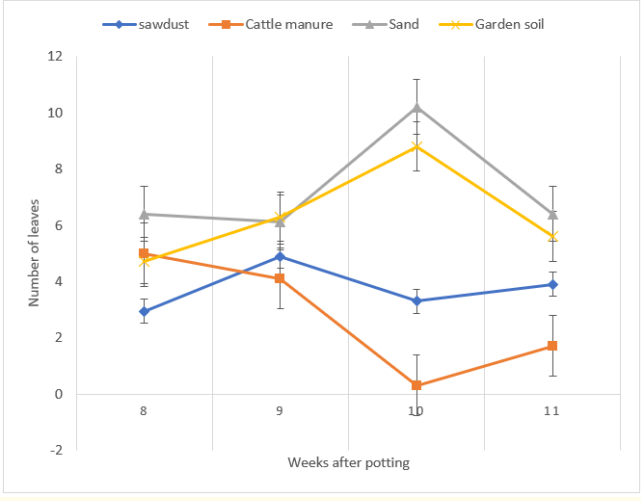

Figure 1: *Effects of different media on the number of leaves from rose cuttings. Vertical bars are standard error (SE) below and above the mean.*

Length of leaves

There were significant ($P < 0.05$) differences in the length of leaves in the different media. The longest leaves (8.8 cm) was obtained from cuttings rooted in sand and the lowest (1.6 cm) were obtained from cuttings propagated in cattle manure. There were no significant ($P > 0.05$) differences in the leaf length between cuttings rooted in sawdust and sand (Figure 2).

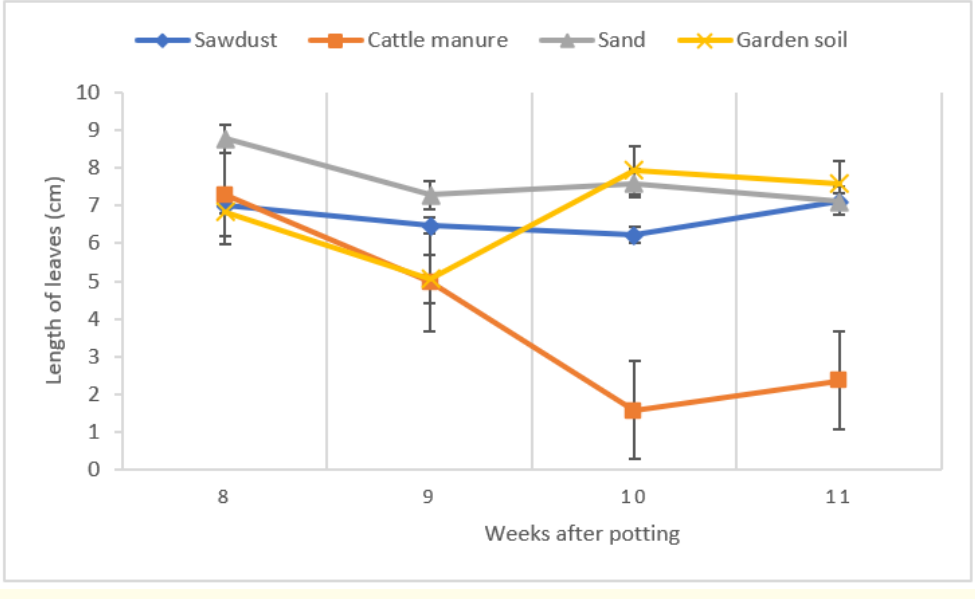

Figure 2: *The effects of different growing media on the length of leaves from rose cuttings. Vertical bars are standard error (SE) below and above the mean.*

Length of roots

There were no significant (P > 0.05) differences in length of roots of rose cuttings rooted in garden soil, sawdust, cattle manure and sand (WAP 8, 9 and 11). There were significant (P < 0.05) differences in length of roots between cuttings grown in sand, sawdust and cattle manure (WAP 10). The longest root (17.5 cm) was obtained in cuttings rooted in the sand and the shortest roots (1.1 cm) was in cuttings rooted using cattle manure. The second best results were obtained from cuttings rooted in garden soil (Figure 3).

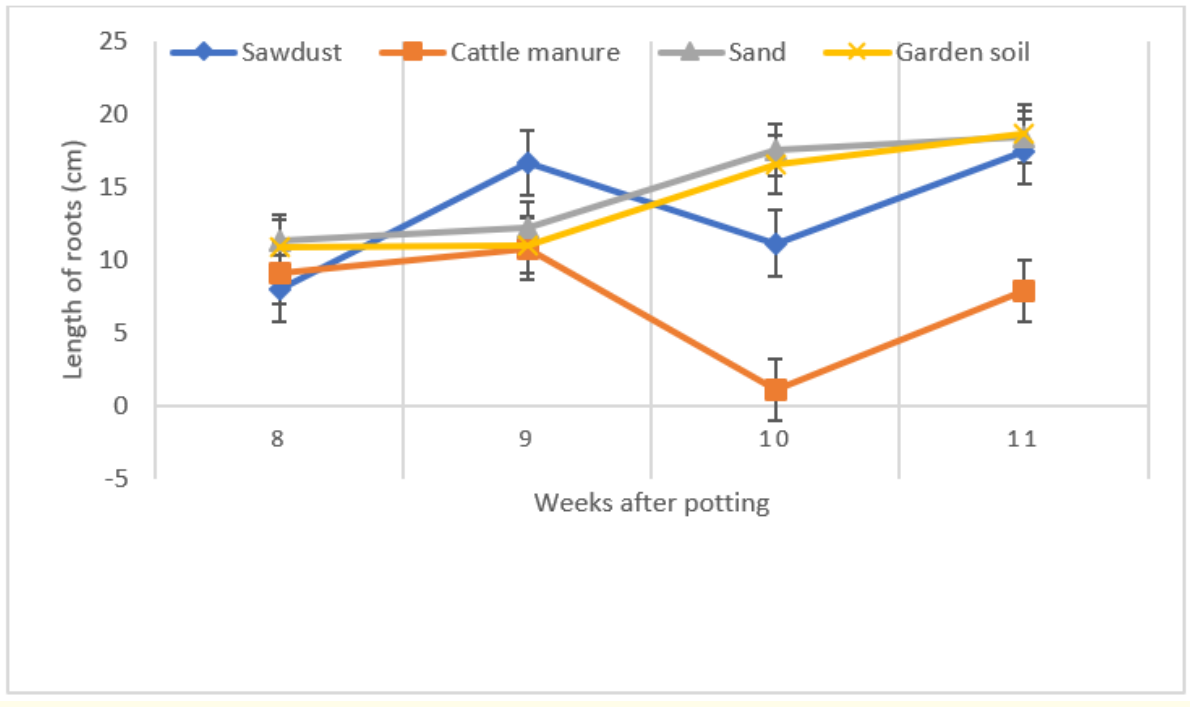

Figure 3: *The effects of different media on the length of roots from rose cuttings. Vertical bars are standard error (SE) below and above the mean.*

Leaves fresh mass

There were no significant (P > 0.05) differences in fresh mass of leaves of roses between cuttings grown in garden soil, sawdust, cattle manure and sand (WAP 8, 9 and 11). There were significant (P < 0.05) differences in fresh mass of leaves between plants grown in sand, sawdust and cattle manure at WAP 10. The highest leaf fresh mass (0.96g) was obtained from cuttings rooted in the sand and the lowest leaf fresh mass (0.05g) was obtained in cuttings rooted using cattle manure. The second best results were obtained from cuttings rooted in garden soil (Figure 4).

Leaves dry mass

There were no significant (P > 0.05) differences in dry mass of leaves of roses between cuttings rooted in garden soil, sawdust, cattle manure and sand (WAP 8, 9 and 11). There were significant (P < 0.05) differences in dry mass of leaves between cuttings rooted in sand, sawdust and cattle manure at WAP10. The highest leaf dry mass (0.38g) was obtained in plants grown in the garden soil and the lowest leaf fresh mass (0.01 g) was obtained in cuttings rooted using cattle manure. The second best results was obtained from plants grown in sand (Figure 5).

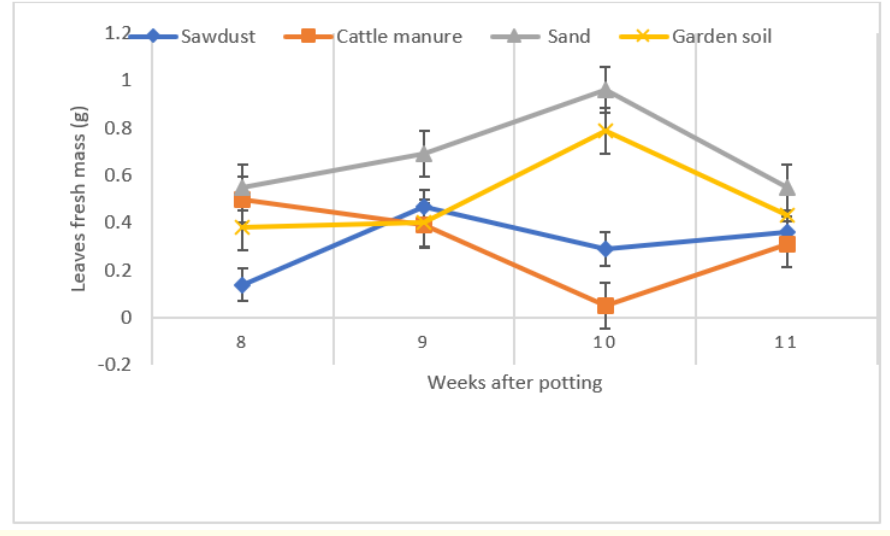

Figure 4: *Effect of different growing media on fresh mass of leaves from rose cuttings. Vertical bars are standard error (SE) below and above the mean.*

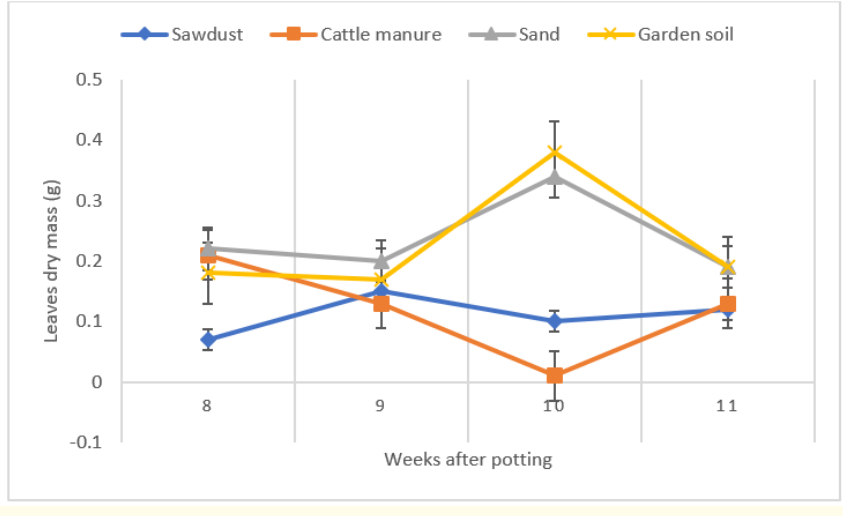

Figure 5: *Effect of different growing media on dry mass of leaves from rose cuttings. Vertical bars are standard error (SE) below and above the mean.*

Roots fresh mass

There were significant ($P < 0.05$) differences in fresh mass of roots of roses between cuttings rooted in sand, garden soil, sawdust and cattle manure at WAP 9. There were no significant ($P > 0.05$) differences in fresh mass of roots between cuttings rooted in sand, sawdust and garden soil (WAP 10 and 11). The highest root fresh mass (0.39g) was obtained in cuttings rooted in the sand and the lowest leaf fresh mass (0.22g) was obtained in cuttings rooted using sawdust. Rose cuttings in cattle manure had no roots. The second best results were obtained from cuttings rooted in garden soil (Figure 6).

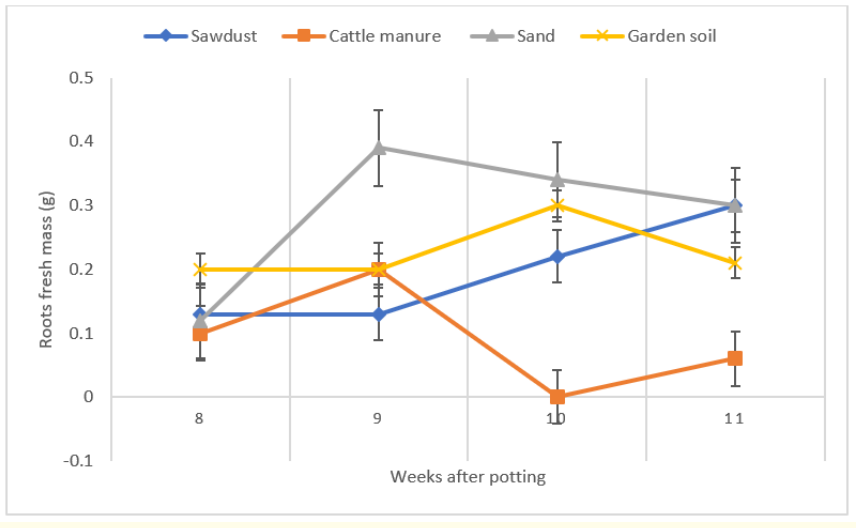

Figure 6: *Effect of different growing media on fresh mass of roots from rose cuttings. Vertical bars are standard error (SE) below and above the mean.*

Roots dry mass

There were significant ($P < 0.05$) differences in dry mass of roots of roses between cuttings rooted in garden soil, sawdust and cattle manure (WAP 10). There were no significant ($P > 0.05$) differences in dry mass of roots between cuttings rooted in sand, sawdust and garden soil (WAP 9, 10 and 11) (Figure 7). The highest root dry mass (0.1g) was obtained in cuttings rooted in the garden soil and the lowest leaf fresh mass (0.04g) was obtained in cuttings rooted using sawdust. Sampled cuttings from cattle manure had no roots. The second best results were obtained from cuttings rooted in sand soil (Figure 7).

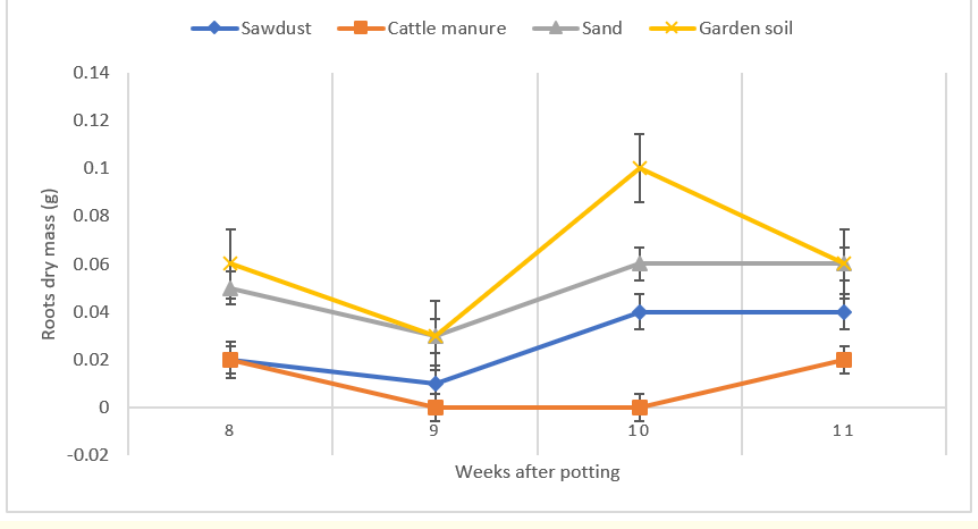

Figure 7: *Effect of different growing media on dry mass of roots from rose cuttings. Vertical bars are standard error (SE) below and above the mean.*

Discussion

Successful rooting of cuttings depend on maintaining adequate moisture in the media and good aeration [25]. The physical structure of a media is a critical factor as this influences the regulation of moisture in media. It is a norm among farmers that the addition of river sand in media increases porosity [26]. This was observed where cuttings rooted in sand had highest number of leaves, length of leaves and fresh mass of leaves. It is reported that the physical property especially sand with large particles sizes presents a higher percentage of pore space suitable for the growth and development of root system including yield [26]. This was also indicated in the shooting of the cuttings, this also implies that the cuttings were are able to shoot out of sand easier.

There was a significant difference in shoot fresh mass of rose grown in different media. There was no significant difference in plant grown in sawdust and sand. Sawdust and sand particles have a high porosity [27]. The highest fresh mass was obtained in plants grown in the sand and garden soil.

Although cuttings propagated in garden soil did not root as vigorously as sand but there was no significant difference in fresh mass and dry mass of roots when compared to the garden soil, sawdust. Garden soil is known for its essential mineral elements [20]. It is also home to billions of micro-organisms which can contribute to the ability of changing a soils chemical and physical properties to support the plant growth [28]. Garden soil has a high moisture retention but poor aeration due to fewer pores in particle arrangement. This could have resulted in the anaerobic conditions which affect root formation and development [2]. Under anaerobic conditions there is insufficient oxygen level, which is required by the root cells hence poor root formation and development as there is minimal carbohydrate formation consequently poor shoot development in treatments with garden soil. Garden soil has a plastic nature when extremely moist it turns muddy [3]. This has the potential to elevate free moisture to the top of the flower pot this moisture is meant for root absorption. This moisture can be evaporated when the temperatures are extremely high as in cases of greenhouse maintenance [18]. This would create a hard crust on the surface of garden soil and compaction of particles which suffocate the roots thus making it rather impossible for roots and shoots to develop [29].

Rooting of cuttings in media with cattle manure as a component was significantly ($P < 0.05$) different (poor performance) when compared to other media. The decomposition rate of cattle manure is very slow, cattle manure is also acidic [26]. This could have caused the poor performance of the treatments with kraal in terms of the rooting and length of roots. Root formation in new cells requires that the media be conducive in soil pH, temperature and nutritional content (micro-organisms). The acidic nature of such a medium can have detrimental effects on new developing roots, likely to toxic as roots choke in acidic state [26,30].

Conclusion

The stem cuttings propagated in sand were most productive in terms of rooting and shooting formation. The worst performing medium was cattle manure.

Recommendations

From the results of this study local ornamental growers may be recommended to use the sand as growing medium for the rooting rose cuttings. Not only the sand can be used but also garden soil and sawdust has good qualities for growing plants but it is readily available and inexpensive for almost all economic classes in the country. However, it is also recommended that a similar study can be carried out to validate the results of the study in an open field or cold frames for those farmers without a lath house.

Appendices

Growing medium	Weeks after potting/number of leaves			
	8	9	10	11
Sawdust	2.9b	4.9a	3.3b	3.9a
Cattle manure	5.0a	4.1a	0.3b	1.7b
Sand	6.5a	6.1a	10.2a	6.4a
Garden soil	4.7a	6.3a	8.8a	5.6a
Significance	**	**	**	**
Coefficient of variation	61.4%	68.4%	47.2%	44.8%
LSD	2.4	2.3	3.9	3.2

Appendix 1: *Effects of different growth media on the number of leaves from rose cuttings.*

***: Shows significance at P=0.05.*

Means followed by the same number are not significantly from one another at (P=0.05). Mean separation.

Growing medium	Weeks after potting/leaf length (cm)			
	8	9	10	11
Sawdust	7a	6.5a	6.2a	7.1a
Cattle manure	7.3a	5.0a	1.6b	2.4b
Sand	8.8a	7.3a	7.6a	7.1a
Garden soil	6.8a	5.1a	7.9a	7.6a
Significance	**	**	**	**
Coefficient of variation	9.7%	27.7%	12.3%	16.3%
LSD	4.47	3.46	3.08	4.27

Appendix 2: *Effects of different growth media on the length of leaves from rose cuttings.*

***: Shows significance at P = 0.05.*

Means followed by the same number are not significantly from one another at (P = 0.05).

Mean separation.

Growing medium	Weeks after potting/root length (cm)			
	8	9	10	11
Sawdust	8.0a	16.6a	11.1b	17.4a
Cattle manure	9.1a	10.7a	1.1c	7.8a
Sand	11.3a	12.2a	17.5a	18.4a
Garden soil	10.8a	11.0a	16.5a	18.6a
Significance	**	**	**	**
Coefficient of variation	21.6%	46.8%	9.3%	35.4%
LSD	7.68	8.41	5.44	15.57

Appendix 3: *Effects of different growth media on length of roots from rose cuttings.*

***: Shows significance at P = 0.05.*

Means followed by the same number are not significantly from one another at (P = 0.05).

Mean separation.

Growing medium	Weeks after potting/leaf fresh mass (g)			
	8	9	10	11
Sawdust	0.14b	0.47a	0.29b	0.36a
Cattle manure	0.5a	0.38a	0.05b	0.31a
Sand	0.55a	0.69a	0.96a	0.55a
Garden soil	0.38a	0.4a	0.79a	0.43a
Significance	**	**	**	**
Coefficient of variation	56.0%	53.9%	27.5%	37.3%
LSD	0.27	0.39	0.36	0.65

Appendix 4: *Effects of different growth media on the fresh mass of leaves from rose cuttings.*

***: Shows significance at P = 0.05.*

Means followed by the same number are not significantly from one another at (P = 0.05).

Mean separation.

Growing medium	Weeks after potting/leaf dry mass (g)			
	8	9	10	11
Sawdust	0.08b	0.15a	0.1b	0.12a
Cattle manure	0.21a	0.13a	0.01b	0.13a
Sand	0.22a	0.2a	0.34a	0.19a
Garden soil	0.18a	0.17a	0.38a	0.19a
Significance	**	**	**	**
Coefficient of variation	60%	65.9%	40.6%	52.2%
LSD	0.12	0.12	0.21	0.22

Appendix 5: *Effects of different growth media on the dry mass of leaves from rose cuttings.*

***: Shows significance at P = 0.05.*

Means followed by the same number are not significantly from one another at (P = 0.05).

Mean separation.

Growing medium	Weeks after potting/root fresh mass (g)			
	8	9	10	11
Sawdust	0.13a	0.13b	0.22a	0.25a
Cattle manure	0.1a	0.19b	0.01b	0.06a
Sand	0.12a	0.39a	0.34a	0.25a
Garden soil	0.2a	0.2b	0.29a	0.21a
Significance	**	**	**	**
Coefficient of variation	43.5%	41.3%	40.3%	47.3%
LSD	0.17	0.17	0.21	0.17

Appendix 6: *Effects of different growth media on the fresh mass of roots from rose cuttings.*

*** shows significance at P = 0.05.*

Means followed by the same number are not significantly from one another at (P = 0.05).

Mean separation.

Growing medium	Weeks after potting/root dry mass (g)			
	8	9	10	11
Sawdust	0.02a	0.01a	0.04a	0.04a
Cattle manure	0.02a	0.01a	0.003b	0.02a
Sand	0.05a	0.03a	0.6a	0.06a
Garden soil	0.06a	0.03a	0.1a	0.06a
Significance	**	**	**	**
Coefficient of variation	82.4%	93.9%	61.6%	51.6%
LSD	0.05	0.03	0.07	0.06

Appendix 7: *Effects of different growth media on the dry mass of roots from rose cuttings.*

***: Shows significance at P = 0.05.*

Means followed by the same number are not significantly from one another at (P = 0.05).

Mean separation.

```
***** Analysis of variance *****

Variate: No_of_leaves_wk8
Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.
REPLICATE stratum          3    103.578     34.526   14.79

REPLICATE.*Units* stratum
TREATMENT                  3     25.641      8.547    3.66   0.057
Residual                   9     21.016      2.335

Total                     15    150.234


***** Tables of means *****

Variate: No_of_leaves_wk8

Grand mean 4.78

 TREATMENT        1        2        3        4
              2.94     5.00     6.50     4.69

*** Standard errors of differences of means ***

Table            TREATMENT
rep.                    4
d.f.                    9
s.e.d.              1.081

*** Least significant differences of means (5% level) ***

Table            TREATMENT
rep.                    4
d.f.                    9
l.s.d.              2.444

***** Stratum standard errors and coefficients of variation *****

Variate: No_of_leaves_wk8

Stratum                   d.f.          s.e.         cv%
REPLICATE                    3         2.938        61.4
REPLICATE.*Units*            9         1.528        32.0
```

Appendix 8: *ANOVA table for effects of different growth media on the number of leaves from rose cuttings at 8 WAP.*

```
***** Analysis of variance *****

Variate: No_of_leaves_wk9
Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.
REPLICATE stratum          3    146.668     48.889   23.12

REPLICATE.*Units* stratum
TREATMENT                  3      8.793      2.931    1.39   0.309
Residual                   9     19.035      2.115

Total                     15    174.496

***** Tables of means *****

Variate: No_of_leaves_wk9

Grand mean   5.11

 TREATMENT        1        2        3        4
              4.94     4.06     6.12     5.31

*** Standard errors of differences of means ***

Table            TREATMENT
rep.                    4
d.f.                    9
s.e.d.              1.028

*** Least significant differences of means (5% level) ***

Table            TREATMENT
rep.                    4
d.f.                    9
l.s.d.              2.326

***** Stratum standard errors and coefficients of variation *****

Variate: No_of_leaves_wk9

Stratum                  d.f.          s.e.         cv%

REPLICATE                   3         3.496        68.4
REPLICATE.*Units*           9         1.454        28.5
```

Appendix 9: *ANOVA table for effects of different growth media on the number of leaves from rose cuttings at 9 WAP.*

```
***** Analysis of variance *****

Variate: No_of_leaves_wk10

Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.

REPLICATE stratum          3     84.500     28.167    4.53

REPLICATE.*Units* stratum
TREATMENT                  3    257.781     85.927   13.82   0.001
Residual                   9     55.969      6.219

Total                     15    398.250

***** Tables of means *****

Variate: No_of_leaves_wk10

Grand mean   5.62

 TREATMENT        1        2        3        4
              3.25     0.31    10.19     8.75

*** Standard errors of differences of means ***

Table            TREATMENT
rep.                    4
d.f.                    9
s.e.d.              1.763

*** Least significant differences of means (5% level) ***

Table            TREATMENT
rep.                    4
d.f.                    9
l.s.d.              3.989

***** Stratum standard errors and coefficients of variation *****

Variate: No_of_leaves_wk10

Stratum                   d.f.          s.e.         cv%

REPLICATE                    3         2.654        47.2
REPLICATE.*Units*            9         2.494        44.3
```

Appendix 10: *ANOVA table for effects of different growth media on the number from leaves of rose cuttings at 10 WAP.*

```
***** Analysis of variance *****
Variate: No_of_leaves_wk11

Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.

REPLICATE stratum          3     46.703     15.568    3.99

REPLICATE.*Units* stratum
TREATMENT                  3     51.891     17.297    4.43   0.036
Residual                   9     35.141      3.905

Total                     15    133.734


***** Tables of means *****

Variate: No_of_leaves_wk11

Grand mean   4.41

 TREATMENT        1        2        3        4
              3.94     1.69     6.38     5.62


*** Standard errors of differences of means ***

Table            TREATMENT
rep.                    4
d.f.                    9
s.e.d.              1.397

*** Least significant differences of means (5% level) ***

Table            TREATMENT
rep.                    4
d.f.                    9
l.s.d.              3.161


***** Stratum standard errors and coefficients of variation *****

Variate: No_of_leaves_wk11

Stratum                  d.f.          s.e.         cv%

REPLICATE                   3         1.973        44.8
REPLICATE.*Units*           9         1.976        44.8
```

Appendix 11: *ANOVA table for effects of different growth media on the number of leaves from rose cuttings at 11 WAP.*

```
***** Analysis of variance *****

Variate: Leaf_length_wk8

Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.

REPLICATE stratum          3      6.268      2.089    0.27

REPLICATE.*Units* stratum
TREATMENT                  3      9.600      3.200    0.41   0.747
Residual                   9     69.558      7.729

Total                     15     85.427

***** Tables of means *****

Variate: Leaf_length_wk8

Grand mean   7.47

 TREATMENT        1        2        3        4
              7.00     7.28     8.78     6.82

*** Standard errors of differences of means ***

Table            TREATMENT
rep.                    4
d.f.                    9
s.e.d.              1.966

*** Least significant differences of means (5% level) ***

Table            TREATMENT
rep.                    4
d.f.                    9
l.s.d.              4.447

***** Stratum standard errors and coefficients of variation *****

Variate: Leaf_length_wk8

Stratum                   d.f.          s.e.         cv%

REPLICATE                    3         0.723         9.7
REPLICATE.*Units*            9         2.780        37.2
```

Appendix 12: *ANOVA table for effects of different growth media on the length of leaves from rose cuttings at 8 WAP.*

```
***** Analysis of variance *****

Variate: Leaf_length_wk9

Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.

REPLICATE stratum          3     32.528     10.843    2.31

REPLICATE.*Units* stratum
TREATMENT                  3     14.959      4.986    1.06   0.412
Residual                   9     42.209      4.690

Total                     15     89.697

***** Tables of means *****

Variate: Leaf_length_wk9

Grand mean   5.95

 TREATMENT        1        2        3        4
              6.47     4.98     7.28     5.07

*** Standard errors of differences of means ***

Table            TREATMENT
rep.                    4
d.f.                    9
s.e.d.              1.531

*** Least significant differences of means (5% level) ***

Table            TREATMENT
rep.                    4
d.f.                    9
l.s.d.              3.464

***** Stratum standard errors and coefficients of variation *****

Variate: Leaf_length_wk9

Stratum                   d.f.          s.e.         cv%

REPLICATE                    3         1.646        27.7
REPLICATE.*Units*            9         2.166        36.4
```

Appendix 13: *ANOVA table for effects of different growth media on the length of leaves from rose cuttings at 9 WAP.*

```
***** Analysis of variance *****

Variate: Leaf_length_wk10

Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.

REPLICATE stratum          3      6.203      2.068    0.56

REPLICATE.*Units* stratum
TREATMENT                  3    102.595     34.198    9.24   0.004
Residual                   9     33.313      3.701

Total                     15    142.111


***** Tables of means *****

Variate: Leaf_length_wk10

Grand mean   5.83

 TREATMENT        1        2        3        4
              6.21     1.59     7.59     7.94


*** Standard errors of differences of means ***

Table            TREATMENT
rep.                    4
d.f.                    9
s.e.d.              1.360

*** Least significant differences of means (5% level) ***

Table            TREATMENT
rep.                    4
d.f.                    9
l.s.d.              3.077


***** Stratum standard errors and coefficients of variation *****

Variate: Leaf_length_wk10

Stratum                  d.f.          s.e.         cv%

REPLICATE                   3         0.719        12.3
REPLICATE.*Units*           9         1.924        33.0
```

Appendix 14: *ANOVA table for effects of different growth media on the length of leaves from rose cuttings at 10 WAP.*

```
***** Analysis of variance *****

Variate: Leaf_length_wk11

Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.

REPLICATE stratum          3     11.629      3.876    0.55

REPLICATE.*Units* stratum
TREATMENT                  3     72.128     24.043    3.38   0.068
Residual                   9     63.996      7.111

Total                     15    147.752


***** Tables of means *****

Variate: Leaf_length_wk11

Grand mean   6.04

 TREATMENT        1        2        3        4
              7.10     2.37     7.12     7.56

*** Standard errors of differences of means ***

Table            TREATMENT
rep.                    4
d.f.                    9
s.e.d.              1.886

*** Least significant differences of means (5% level) ***

Table            TREATMENT
rep.                    4
d.f.                    9
l.s.d.              4.265

***** Stratum standard errors and coefficients of variation *****

Variate: Leaf_length_wk11

Stratum                  d.f.          s.e.         cv%

REPLICATE                   3         0.984        16.3
REPLICATE.*Units*           9         2.667        44.2
```

Appendix 15: *ANOVA table for effects of different growth media on the length of leaves from rose cuttings at 11 WAP.*

```
***** Analysis of variance *****

Variate: Longest_root_wk8

Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.

REPLICATE stratum          3      54.17      18.06    0.78

REPLICATE.*Units* stratum
TREATMENT                  3      29.71       9.90    0.43   0.737
Residual                   9     207.43      23.05

Total                     15     291.31


***** Tables of means *****

Grand mean   9.8

 TREATMENT        1        2        3        4
                8.0      9.1     11.4     10.8


*** Standard errors of differences of means ***

Table            TREATMENT
rep.                    4
d.f.                    9
s.e.d.               3.39

*** Least significant differences of means (5% level) ***

Table            TREATMENT
rep.                    4
d.f.                    9
l.s.d.               7.68


***** Stratum standard errors and coefficients of variation *****


Stratum                  d.f.          s.e.         cv%

REPLICATE                   3          2.12        21.6
REPLICATE.*Units*           9          4.80        48.8
```

Appendix 16: *ANOVA table for effects of different growth media on the length of roots from rose cuttings at 8 WAP.*

```
***** Analysis of variance *****

Variate: longest_root_wk9

Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.

REPLICATE stratum          3     419.50     139.83    5.06

REPLICATE.*Units* stratum
TREATMENT                  3      88.75      29.58    1.07   0.409
Residual                   9     248.59      27.62

Total                     15     756.83


***** Tables of means *****

Grand mean   12.6

 TREATMENT        1        2        3        4
              16.6     10.7     12.2     11.0


*** Standard errors of differences of means ***

Table            TREATMENT
rep.                    4
d.f.                    9
s.e.d.               3.72

*** Least significant differences of means (5% level) ***

Table            TREATMENT
rep.                    4
d.f.                    9
l.s.d.               8.41


***** Stratum standard errors and coefficients of variation *****

Stratum                  d.f.          s.e.         cv%

REPLICATE                   3          5.91        46.8
REPLICATE.*Units*           9          5.26        41.6
```

Appendix 17: *ANOVA table for effects of different growth media on the length of roots from rose cuttings at 9 WAP.*

```
***** Analysis of variance *****

Variate: loongest_root_wk10

Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.

REPLICATE stratum          3      13.92       4.64    0.40

REPLICATE.*Units* stratum
TREATMENT                  3     681.52     227.17   19.63   <.001
Residual                   9     104.18      11.58

Total                     15     799.61


***** Tables of means *****

Grand mean   11.53

 TREATMENT        1        2        3        4
             11.07     1.05    17.50    16.50


*** Standard errors of differences of means ***

Table            TREATMENT
rep.                    4
d.f.                    9
s.e.d.              2.406

*** Least significant differences of means (5% level) ***

Table            TREATMENT
rep.                    4
d.f.                    9
l.s.d.              5.442


***** Stratum standard errors and coefficients of variation *****

Stratum                  d.f.          s.e.         cv%

REPLICATE                   3         1.077         9.3
REPLICATE.*Units*           9         3.402        29.5
```

Appendix 18: *ANOVA table for effects of different growth media on the length of roots from rose cuttings at 10 WAP.*

```
***** Analysis of variance *****

Variate: Longest_root_wk11

Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.

REPLICATE stratum          3     362.14     120.71    1.27

REPLICATE.*Units* stratum
TREATMENT                  3     325.19     108.40    1.14   0.383
Residual                   9     852.75      94.75

Total                     15    1540.08


***** Tables of means *****

Grand mean   15.5

 TREATMENT        1        2        3        4
              17.4      7.8     18.4     18.6


*** Standard errors of differences of means ***

Table            TREATMENT
rep.                    4
d.f.                    9
s.e.d.               6.88

*** Least significant differences of means (5% level) ***

Table            TREATMENT
rep.                    4
d.f.                    9
l.s.d.              15.57


***** Stratum standard errors and coefficients of variation *****

Stratum                  d.f.          s.e.         cv%

REPLICATE                   3          5.49        35.4
REPLICATE.*Units*           9          9.73        62.7
```

Appendix 19: *ANOVA table for effects of different growth media on the length of roots from rose cuttings at 11 WAP.*

```
***** Analysis of variance *****

Variate: Fresh_mass_leaves_wk8

Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.

REPLICATE stratum          3    0.58071    0.19357    7.03

REPLICATE.*Units* stratum
TREATMENT                  3    0.40510    0.13503    4.91   0.027
Residual                   9    0.24770    0.02752

Total                     15    1.23351


***** Tables of means *****

Grand mean   0.393

 TREATMENT        1        2        3        4
              0.139    0.504    0.549    0.381


*** Standard errors of differences of means ***

Table            TREATMENT
rep.                    4
d.f.                    9
s.e.d.             0.1173

*** Least significant differences of means (5% level) ***

Table            TREATMENT
rep.                    4
d.f.                    9
l.s.d.             0.2654


***** Stratum standard errors and coefficients of variation ****

Stratum                  d.f.          s.e.         cv%

REPLICATE                   3        0.2200        56.0
REPLICATE.*Units*           9        0.1659        42.2
```

Appendix 20: *ANOVA table for effects of different growth media on the fresh mass of leaves from rose cuttings at 8 WAP.*

```
***** Analysis of variance *****

Variate: Fresh_mass_leaves_wk9

Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.

REPLICATE stratum          3    0.81634    0.27211    4.57

REPLICATE.*Units* stratum
TREATMENT                  3    0.23759    0.07920    1.33   0.325
Residual                   9    0.53623    0.05958

Total                     15    1.59016


***** Tables of means *****

Grand mean   0.484

 TREATMENT        1        2        3        4
             0.466    0.378    0.688    0.404


*** Standard errors of differences of means ***

Table            TREATMENT
rep.                    4
d.f.                    9
s.e.d.             0.1726

*** Least significant differences of means (5% level) ***

Table            TREATMENT
rep.                    4
d.f.                    9
l.s.d.             0.3904


***** Stratum standard errors and coefficients of variation *****

Stratum                  d.f.          s.e.         cv%

REPLICATE                   3        0.2608        53.9
REPLICATE.*Units*           9        0.2441        50.4
```

Appendix 21: *ANOVA table for effects of different growth media on the fresh mass of leaves from rose cuttings at 9 WAP.*

```
***** Analysis of variance *****

Variate: Fresh_mass_leaves_wk10

Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.

REPLICATE stratum          3    0.24991    0.08330    1.67

REPLICATE.*Units* stratum
TREATMENT                  3    2.17560    0.72520   14.52
<.001
Residual                   9    0.44939    0.04993

Total                     15    2.87491


***** Tables of means *****


Grand mean   0.524

 TREATMENT        1        2        3        4
             0.291    0.051    0.964    0.791


*** Standard errors of differences of means ***

Table            TREATMENT
rep.                    4
d.f.                    9
s.e.d.             0.1580

*** Least significant differences of means (5% level) ***

Table            TREATMENT
rep.                    4
d.f.                    9
l.s.d.             0.3574


***** Stratum standard errors and coefficients of variation *****

Stratum                  d.f.          s.e.         cv%

REPLICATE                   3        0.1443        27.5
REPLICATE.*Units*           9        0.2235        42.6
```

Appendix 22: *ANOVA table for effects of different growth media on the fresh mass of leaves from rose cuttings at 10 WAP.*

```
***** Analysis of variance *****

Variate: Fresh_mass_leaves_wk11

Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.

REPLICATE stratum          3     0.2846     0.0949    0.58

REPLICATE.*Units* stratum
TREATMENT                  3     0.1248     0.0416    0.25 0.857
Residual                   9     1.4739     0.1638

Total                     15     1.8834


***** Tables of means *****

Grand mean   0.41

 TREATMENT        1        2        3        4
              0.36     0.31     0.55     0.43


*** Standard errors of differences of means ***

Table            TREATMENT
rep.                    4
d.f.                    9
s.e.d.              0.286

*** Least significant differences of means (5% level) ***

Table            TREATMENT
rep.                    4
d.f.                    9
l.s.d.              0.647


***** Stratum standard errors and coefficients of variation

Stratum                  d.f.          s.e.         cv%

REPLICATE                   3         0.154        37.3
REPLICATE.*Units*           9         0.405        98.1
```

Appendix 23: *ANOVA table for effects of different growth media on the fresh mass of leaves from rose cuttings at 11 WAP.*

```
***** Analysis of variance *****

Variate: Dry_mass_leaves_wk8

Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.

REPLICATE stratum          3   0.130232   0.043411    7.52

REPLICATE.*Units* stratum
TREATMENT                  3   0.051839   0.017280    2.99   0.088
Residual                   9   0.051966   0.005774

Total                     15   0.234037


***** Tables of means *****

Grand mean   0.174

 TREATMENT        1        2        3        4
             0.078    0.214    0.220    0.183


*** Standard errors of differences of means ***

Table            TREATMENT
rep.                    4
d.f.                    9
s.e.d.             0.0537

*** Least significant differences of means (5% level) ***

Table            TREATMENT
rep.                    4
d.f.                    9
l.s.d.             0.1215


***** Stratum standard errors and coefficients of variation *****

Stratum                  d.f.          s.e.         cv%

REPLICATE                   3        0.1042        60.0
REPLICATE.*Units*           9        0.0760        43.8
```

Appendix 24: *ANOVA table for effects of different growth media on the dry mass of leaves from rose cuttings at 8 WAP.*

```
***** Analysis of variance *****

Variate: Dry_mass_leaves_wk9

Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.

REPLICATE stratum          3   0.136372   0.045457    7.49

REPLICATE.*Units* stratum
TREATMENT                  3   0.012766   0.004255    0.70 0.575
Residual                   9   0.054656   0.006073

Total                     15   0.203794


***** Tables of means *****

Grand mean   0.162

 TREATMENT        1        2        3        4
             0.148    0.125    0.201    0.174


*** Standard errors of differences of means ***

Table            TREATMENT
rep.                    4
d.f.                    9
s.e.d.             0.0551

*** Least significant differences of means (5% level) ***

Table            TREATMENT
rep.                    4
d.f.                    9
l.s.d.             0.1247


***** Stratum standard errors and coefficients of variation *****

Stratum                  d.f.          s.e.         cv%

REPLICATE                   3        0.1066        65.9
REPLICATE.*Units*           9        0.0779        48.1
```

Appendix 25: *ANOVA table for effects of different growth media on the dry mass of leaves from rose cuttings at 9 WAP.*

```
***** Analysis of variance *****

Variate: Dry_mass_leaves_wk10

Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.

REPLICATE stratum          3    0.08599    0.02866    1.56

REPLICATE.*Units* stratum
TREATMENT                  3    0.39134    0.13045    7.08
0.010
Residual                   9    0.16574    0.01842

Total                     15    0.64306


***** Tables of means *****

Grand mean   0.208

 TREATMENT        1        2        3        4
              0.100    0.011    0.342    0.379


*** Standard errors of differences of means ***

Table            TREATMENT
rep.                    4
d.f.                    9
s.e.d.             0.0960

*** Least significant differences of means (5% level) ***

Table            TREATMENT
rep.                    4
d.f.                    9
l.s.d.             0.2171


***** Stratum standard errors and coefficients of variation *****

Stratum                  d.f.          s.e.         cv%

REPLICATE                   3        0.0846        40.6
REPLICATE.*Units*           9        0.1357        65.2
```

Appendix 26: *ANOVA table for effects of different growth media on the dry mass of leaves from rose cuttings at 10 WAP.*

```
***** Analysis of variance *****

Variate: Dry_mass_leaves_wk11

Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.

REPLICATE stratum          3    0.07907    0.02636    1.35

REPLICATE.*Units* stratum
TREATMENT                  3    0.01751    0.00584    0.30   0.826
Residual                   9    0.17610    0.01957

Total                     15    0.27268


***** Tables of means *****

Grand mean   0.155

 TREATMENT        1        2        3        4
             0.119    0.126    0.191    0.186


*** Standard errors of differences of means ***

Table            TREATMENT
rep.                    4
d.f.                    9
s.e.d.             0.0989

*** Least significant differences of means (5% level) ***

Table            TREATMENT
rep.                    4
d.f.                    9
l.s.d.             0.2238


***** Stratum standard errors and coefficients of variation *****

Stratum                  d.f.          s.e.         cv%

REPLICATE                   3        0.0812        52.2
REPLICATE.*Units*           9        0.1399        90.0
```

Appendix 27: *ANOVA table for effects of different growth media on the dry mass of leaves from rose cuttings at 11 WAP.*

```
***** Analysis of variance *****

Variate: Fresh_mass_roots_wk8

Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.

REPLICATE stratum          3    0.04188    0.01396    1.18

REPLICATE.*Units* stratum
TREATMENT                  3    0.02321    0.00774    0.65   0.601
Residual                   9    0.10655    0.01184

Total                     15    0.17164


***** Tables of means *****

Grand mean   0.136

 TREATMENT        1        2        3        4
             0.127    0.095    0.123    0.198


*** Standard errors of differences of means ***

Table            TREATMENT
rep.                    4
d.f.                    9
s.e.d.             0.0769

*** Least significant differences of means (5% level) ***

Table            TREATMENT
rep.                    4
d.f.                    9
l.s.d.             0.1740


***** Stratum standard errors and coefficients of variation *****

Stratum                  d.f.          s.e.         cv%

REPLICATE                   3        0.0591        43.5
REPLICATE.*Units*           9        0.1088        80.1
```

Appendix 28: *ANOVA table for effects of different growth media on the fresh mass of roots from rose cuttings at 8 WAP.*

```
***** Analysis of variance *****

Variate: Fresh_mass_roots_wk9

Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.

REPLICATE stratum          3    0.10578    0.03526    2.95

REPLICATE.*Units* stratum
TREATMENT                  3    0.15099    0.05033    4.21   0.041
Residual                   9    0.10754    0.01195

Total                     15    0.36431


***** Tables of means *****

Grand mean   0.227

 TREATMENT        1        2        3        4
             0.131    0.192    0.389    0.195


*** Standard errors of differences of means ***

Table            TREATMENT
rep.                    4
d.f.                    9
s.e.d.             0.0773

*** Least significant differences of means (5% level) ***

Table            TREATMENT
rep.                    4
d.f.                    9
l.s.d.             0.1749


***** Stratum standard errors and coefficients of variation *****

Stratum                  d.f.          s.e.         cv%

REPLICATE                   3        0.0939        41.3
REPLICATE.*Units*           9        0.1093        48.1
```

Appendix 29: *ANOVA table for effects of different growth media on the fresh mass of roots from rose cuttings at 9 WAP.*

```
***** Analysis of variance *****

Variate: Fresh_mass_roots_wk10

Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.

REPLICATE stratum          3    0.09245    0.03082    1.80

REPLICATE.*Units* stratum
TREATMENT                  3    0.25982    0.08661    5.07   0.025
Residual                   9    0.15384    0.01709

Total                     15    0.50610


***** Tables of means *****

Grand mean   0.218

 TREATMENT        1        2        3        4
             0.224    0.009    0.343    0.293


*** Standard errors of differences of means ***

Table            TREATMENT
rep.                    4
d.f.                    9
s.e.d.             0.0924

*** Least significant differences of means (5% level) ***

Table            TREATMENT
rep.                    4
d.f.                    9
l.s.d.             0.2091


***** Stratum standard errors and coefficients of variation *****

Stratum                  d.f.          s.e.         cv%

REPLICATE                   3        0.0878        40.3
REPLICATE.*Units*           9        0.1307        60.1
```

Appendix 30: *ANOVA table for effects of different growth media on the fresh mass of roots from rose cuttings at 10 WAP.*

```
***** Analysis of variance *****

Variate: Fresh_mass_roots_wk11

Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.

REPLICATE stratum          3    0.09986    0.03329    3.05

REPLICATE.*Units* stratum
TREATMENT                  3    0.09886    0.03295    3.02   0.087
Residual                   9    0.09825    0.01092

Total                     15    0.29697


***** Tables of means *****

Grand mean   0.193

 TREATMENT        1        2        3        4
             0.251    0.060    0.251    0.208


*** Standard errors of differences of means ***

Table            TREATMENT
rep.                    4
d.f.                    9
s.e.d.             0.0739

*** Least significant differences of means (5% level) ***

Table            TREATMENT
rep.                    4
d.f.                    9
l.s.d.             0.1671


***** Stratum standard errors and coefficients of variation *****

Stratum                  d.f.          s.e.         cv%

REPLICATE                   3        0.0912        47.3
REPLICATE.*Units*           9        0.1045        54.2
```

Appendix 31: *ANOVA table for effects of different growth media on the fresh mass of roots from rose cuttings at 11 WAP.*

```
***** Analysis of variance *****

Variate: Dry_mass_roots_wk8

Source of variation     d.f.       s.s.       m.s.    v.r.    F pr.

REPLICATE stratum          3   0.0106167   0.0035389    4.03

REPLICATE.*Units* stratum
TREATMENT                  3   0.0043347   0.0014449    1.65   0.247
Residual                   9   0.0078945   0.0008772

Total                     15   0.0228459


***** Tables of means *****

Grand mean   0.0361

 TREATMENT        1        2        3        4
             0.0188   0.0213   0.0475   0.0569


*** Standard errors of differences of means ***

Table            TREATMENT
rep.                     4
d.f.                     9
s.e.d.             0.02094

*** Least significant differences of means (5% level) ***

Table            TREATMENT
rep.                     4
d.f.                     9
l.s.d.             0.04737


***** Stratum standard errors and coefficients of variation

Stratum                  d.f.          s.e.         cv%

REPLICATE                   3       0.02974        82.4
REPLICATE.*Units*           9       0.02962        82.0
```

Appendix 32: *ANOVA table for effects of different growth media on the dry mass of roots from rose cuttings at 8 WAP.*

```
***** Analysis of variance *****

Variate: Dry_mass_roots_wk9

Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.

REPLICATE stratum          3   0.0048512   0.0016171    4.73

REPLICATE.*Units* stratum
TREATMENT                  3   0.0023949   0.0007983    2.33   0.142
Residual                   9   0.0030785   0.0003421

Total                     15    0.0103246


***** Tables of means *****

Grand mean   0.0214

 TREATMENT        1        2        3        4
             0.0125   0.0063   0.0338   0.0331


*** Standard errors of differences of means ***

Table            TREATMENT
rep.                    4
d.f.                    9
s.e.d.            0.01308

*** Least significant differences of means (5% level) ***

Table            TREATMENT
rep.                    4
d.f.                    9
l.s.d.            0.02958


***** Stratum standard errors and coefficients of variation *****

Stratum                  d.f.          s.e.         cv%

REPLICATE                   3       0.02011        93.9
REPLICATE.*Units*           9       0.01849        86.4
```

Appendix 33: *ANOVA table for effects of different growth media on the dry mass of roots of rose cuttings at 9 WAP.*

```
***** Analysis of variance *****

Variate: Dry_mass_roots_wk10

Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.

REPLICATE stratum          3   0.010876   0.003625    1.84

REPLICATE.*Units* stratum
TREATMENT                  3   0.018948   0.006316    3.20   0.077
Residual                   9   0.017775   0.001975

Total                     15   0.047600


***** Tables of means *****

Grand mean   0.049

 TREATMENT        1        2        3        4
             0.037    0.003    0.057    0.098


*** Standard errors of differences of means ***

Table            TREATMENT
rep.                    4
d.f.                    9
s.e.d.             0.0314

*** Least significant differences of means (5% level) ***

Table            TREATMENT
rep.                    4
d.f.                    9
l.s.d.             0.0711


***** Stratum standard errors and coefficients of variation *****

Stratum                  d.f.          s.e.         cv%

REPLICATE                   3        0.0301        61.6
REPLICATE.*Units*           9        0.0444        90.9
```

Appendix 34: *ANOVA table for effects of different growth media on the dry mass of roots from rose cuttings at 10 WAP.*

```
***** Analysis of variance *****

Variate: Dry_mass_roots_wk11

Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.

REPLICATE stratum          3   0.007677   0.002559    2.03

REPLICATE.*Units* stratum
TREATMENT                  3   0.004552   0.001517    1.20   0.363
Residual                   9   0.011345   0.001261

Total                     15   0.023573


***** Tables of means *****

Grand mean   0.0491

 TREATMENT        1        2        3        4
             0.0437   0.0238   0.0644   0.0644


*** Standard errors of differences of means ***

Table            TREATMENT
rep.                    4
d.f.                    9
s.e.d.            0.02511

*** Least significant differences of means (5% level) ***

Table            TREATMENT
rep.                    4
d.f.                    9
l.s.d.            0.05679


***** Stratum standard errors and coefficients of variation *****

Stratum                  d.f.          s.e.         cv%

REPLICATE                   3       0.02529        51.6
REPLICATE.*Units*           9       0.03550        72.4
```

Appendix 35: *ANOVA table for effects of different growth media on the dry mass of roots from rose cuttings at 11 WAP.*

Dedication

This work is dedicated to the Ndlangamandla and Fakudze families, alongside my siblings for the continuous love and support they have given me throughout my educational journey. I also bestow my work to my beloved son Melokuhle Junior Fakudze for the undivided love and belief in me. This is also in loving memory of my mom Mrs. K. I. Phakathi who passed on the 9th of August 2017, may her soul rest in eternal peace.

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