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INDIGENOUS KNOWLEGDE OF BUSH TEA (*ATHRIXIA PHYLICOIDES*) AND EFFECT OF FERTIGATION FREQUENCY AND GROWING MEDIUM ON PLANT GROWTH

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ATHRIXIA PHYLICOIDES

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Indigenous knowledge of bush tea (*Athrixia phylicoides*) and effect of fertigation frequency and growing medium on plant growth

By

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Submitted in partial fulfilment of the requirements for the degree

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Department of Plant Production and Soil Science

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University of Pretoria

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DECLARATION

I declare that this dissertation, which is submitted for the **degree M. INST. AGRAR: Plant Production (Horticulture)** at the University of Pretoria, is my own work and has not previously been submitted to any other tertiary institution. Work by other authors that served as sources of information have been duly acknowledged.

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Zwokunda Juliet Rakuambo Date

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ABSTRACT

Bush tea (*Athrixia phylicoides)* is a medicinal herbal tea, which is used for cleansing or purifying the blood, treating boils, bad acne as well as infected wounds and cuts. *A. phylicoides* also has the potential to be used as an ornamental cut flower due to its beautiful flowers. Because of the many uses of bush tea, it faces problems of being over harvested and exploited. Therefore, there is a need to study more about the plant for possible domestication.

A questionnaire survey was conducted in selected villages of Thohoyandou and Nzhelele in Venda, Limpopo Province, by means of personal interviews. The aim of the survey was to gather indigenous knowledge and validate the uses of bush tea from the local people. Interviews were conducted on three types of respondents, viz. traditional healers (31 %), street sellers (25 %) and bearers of indigenous knowledge (44 %). A total of one hundred respondents were interviewed. One important finding of the study was that people from the area of study possess a remarkable knowledge of the plant and its uses to treat a wide range of physical ailments. The bush tea plant is used as

medicine, health tea as well as a traditional broom. Some of these ailments that could be treated using bush tea were headaches, stomachache, influenza and leg wounds. It is known to have aphrodisiac properties and it can also be used to cleanse the womb, kidney, and veins and to purify blood. The plant was harvested in different ways depending on the reason for harvesting. Results from the survey indicated that the majority of the respondents had no interest in propagating the bush tea plant, few respondents showed interest in propagating the plant. They also showed enhanced knowledge about the uses of other medicinal plants.

A tunnel experiment was also conducted at the Hatfield Experimental Farm of the University of Pretoria in South Africa. The effects of growing media (pine bark and sand) and fertigation frequencies (0.4 ℓ/day, 1 ℓ/day, 2 ℓ/day, 2 ℓ/2nd day and 2 ℓ/ week) on growth and yield of bush tea were studied. Growing media and fertigation frequencies significantly affected the growth performance and yield of bush tea. The growth rate of bush tea between the autumn season and winter season was higher than between winter and spring season. Greater number of stems and shoots were observed in sand grown plants as compared to pine bark grown plants. Sand grown plants had a higher root mass as compared to those of pine bark grown plants over both seasons, with non-significant differences in the dry root mass in winter (90 days after planting). Plants grown in sand had significantly longer roots ($P \leq 0,05$) than plants grown in pine bark at 90 days after planting. However, at 180 days after planting the differences in root lengths were no longer significant.

Fertigation frequencies caused significant differences in growth performance and yield of bush tea. Plants fertigated with 1 ℓ/day were significantly the tallest, followed by plants fertigated with 0.4 ℓ/day, 2 ℓ/day, 2 ℓ/2nd day and 2 ℓ/ week. Our results confirmed that bush tea could grow up to 1 metre high (1.08 m). In addition, fertigation frequency of 1 ℓ/day resulted in plants with greater stem and leaf mass (both fresh and dry), thus higher yields. Fertigation frequency of 2 ℓ/day was found to be too high and hence reduced oxygen supply to the roots and consequently retarded above plant growth. Sand grown plants also produced more flowers than pine bark grown plants. Overall, plants grown in

sand media had superior stem and shoot mass, leaf mass, root mass and flower mass compared to plants grown in pine bark. Plants that received insufficient amount of water (2 ℓ /week) resulted in stunted growth and produced the least yield. In conclusion, bush tea plants performed better in sand growth media than in pine bark growth media. An optimum application rate of 1 ℓ/day was ideal for growth and performance of bush tea as the plant performed better under this fertigation frequency.

Keywords: Traditional healer, indigenous knowledge, fertigation frequency, sand, pine bark, *Athrixia phylicoides*

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CHAPTER 1

GENERAL INTRODUCTION

There are some 30 000 species of higher plants with a high degree of endemism, particularly in Cape Floral Kingdom and the Succulent Karoo vegetation type, that are known to be the main source of drug therapy in traditional medicine (Afolayan,1996; Gericke, 2002). It has been estimated that between 12 and 15 million of South Africans still depend on traditional herbal medicine, from as many as 700 indigenous species, and it is not surprising to find that about 3 500 plants are used as medicine (Afolayan, 1996; Swanepoel, 1997). In South Africa alone, there are an estimated 200 000 indigenous traditional healers, who are consulted by about 60% of the population of the country (Gericke, 1996; Van Wyk, van Oudtshoorn & Gericke, 2002). The high demand for traditional medicine leads to increased commercialization of medicinal plants. One of the plants used for medicinal purposes in South Africa is *Athrixia phylicoides*.

Athrixia phylicoides is a member of the Asteraceae family and is commonly known as bush tea and sometimes called bushman's tea (Gericke, 2002). Asteraceae is one of the largest and probably one of the most advanced plant families that occur throughout the world (Swanepoel, 1997). Some Asteraceae species from other parts of the world have long been used in folk medicine. The family comprises of 900 genera and 17 000 species. In southern Africa, 107 genera and 2 245 species have been identified (Swanepoel, 1997). According to Swanepoel (1997), many species of southern Africa's Asteraceae are also used extensively as traditional medicine. For example, most of the plants used for medicine by indigenous communities in the Western Cape belong to the Asteraceae family (Salie, Eagles & Leng, 1996).

Plants from the Asteraceae family could be annual or perennial herbs, shrubs or even trees in tropical areas (Baumgharrdt, 1998). Leaves of the Asteraceae family are mainly alternate. The flowers are mostly small to tiny and are arranged in a closed head in a common receptacle, which is subtended by bracts, with an outer ring of ray flowers and an inner ring of disk flowers (Salie, Eagles & Leng, 1996). Bush tea is widely distributed throughout the eastern parts of South Africa and neighbouring countries, such as Zoutpansberg in the Limpopo Province, Swaziland, Kwazulu-Natal, Eastern Cape Province and also in Zimbabwe and in the marginal shrub forests (Young & Fox, 1982).

Bush tea is a small erect beautiful shrub, branched with thin, white woolly stems, small dark green pointed leaves and small pink or mauvy pink flowers. Bush tea plant can grow up to 1 m high. The flowers vary from the palest pink to all shades of pink and mauve to deep purple, depending on the soil type and area. Flowering occurs from May (autumn) to July (winter) (Young & Fox, 1982; Roberts, 1990; Swanepoel, 1997).

Bush tea has been used before by different ethnic groups, For example in Venda, bush tea is believed to have aphrodisiac properties (van Wyk & Gericke, 2000). The Vha-Venda people use the extract from the soaked roots and leaves as a medicine. The dried or fresh leaves are boiled and the extract is drunk with sugar as a tea beverage (Mabogo, 1990; Swanepoel, 1997).

According to different authors, the tea from this plant is also excellent for coughs and as a gargle for throat infection and loss of voice. The Zulu and Lobedu people use an infusion of the herb as a tea. The Lobedu people also chew the leaf and swallow the juice as a cough remedy, while the Zulu people use a decoction of the roots as a cough remedy and as a purgative. An infusion of all the plant parts is also used as a blood purifier or boiled by the Zulu people and the whites of South Africa for the relief of sore feet. However, the Southern Sotho bath themselves after scarifying themselves with the decoction of the leaves of *A. phylicoides* or the root of *A. elata* for the relief of sore feet (Watt & Breyer-Brandwijk, 1962; Roberts, 1990; Hutching, Scott, Lewis & Cunningham, 1996; Swanepoel, 1997).

Bush tea is a multi-purpose shrub. Its uses range from a healthy tea that is obtained from boiling dried or fresh leaves to being used as a broom (van Wyk & Gericke, 2000). *A. phylicoides* also has the potential to be used as an aesthetic ornamental cut flower due to its attractive purple flowers. In the ornamental industry, plants from the Asteraceae are commonly grown in gardens. Because of the many uses of bush tea, it faces the problem of being over harvested in the wild. Therefore, there is a need to further study the plant for possible domestication.

The objectives of the research were:

- To conduct a survey on indigenous knowledge in order to validate the uses of bush tea in traditional medicine from the local people in certain areas of Venda.
- To determine bush tea plant growth responses under a plastic covered tunnel in two different growing media (pine bark and sand) and subjected to different fertigation frequencies over time.

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CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

A survey on indigenous knowledge of the plant was conducted as the first trial in this study. As a second trial, the cultivation methods of bush tea were investigated. Cultivation of bush tea with different fertigation frequencies and growing media has never been approached before under a semi-controlled environment (tunnel). Therefore, aspects that will be covered in this chapter are general information on herbal teas, indigenous knowledge as well as general greenhouse production, growing media and fertigation in order to give a better understanding of the objectives of the trials conducted.

2.2 HERBAL TEAS

Instead of caffeine-containing beverages like black tea, coffee and cocoa, there are various herbal teas used for medicine. Today herbal tea cultivation is a big business in many parts of the world and the complex industry now produces a variety of teas (Peter, 1995). India and China produced about half of this output, with most of it for internal consumption. China and Japan produce mainly green tea and partially fermented teas. The world's largest importers of tea are the United Kingdom. South Africa is well known for the production of Rooibos and Honey tea, but it also produces black tea. However, most of it is consumed locally (Africantea, 2004). Lavender, lemon verbena, lemon balm, fever tea and pepper mint are also the popular herbs and ingredients for making tea in South Africa (Van Wijk, 1986).

Certain parts of the world are better known than others for producing herbs. For example, hibiscus is mainly grown native in Africa and Mexico, rosehips in South America and blackberry in Eastern Europe (Peter, 1995; Anonymous, 2002). Herbal teas are primarily made from roots, berries and leaves of different plant materials. The leaves of the true tea plant or black tea (*Camellia sinensis*) are not added to the teas, but other sources are added. For example, blossom of linden, leaves of peppermint and fruit of hibiscus (Trevisanato & Kim, 2000). Herbal teas have a long history of helping people to stay healthy. In the past years, herbal teas seemed to have had a much greater role in everyday living. They were not popular for their flavor, but were taken often medically to cure coughs, sore throats, fever and headaches. For example, tea made from the rootstock of comfrey was believed to heal broken bones, to be a good gargle for sore throat and to cure bleeding gums. The taste of various herbal teas is one thing that one could agree upon. Many teas are full of flavor, and some of these herbal teas are strong and medicinal. Popular and commonly drunk teas include chamomile, marjoram, peppermint, rosemary, sage, rose, lemon verbena and thyme (Koff, 1995; Pietta, 2000; Trevisanato & Kim, 2000).

The process of growing herbal tea is completely natural from the start to the end, which accounts for much of the herbal tea's inherent goodness and flavor. As opposed to the elaborate wilting, rolling, fermenting and firing process used to manufacture black tea, the steps in preparing herbal tea are extremely simple. After harvest, the herbs are dried either on large screens or tied in bundles and hanged upside down (Koff, 1995; Peter, 1995). Three final products, namely pills, powders, and teas are used commercially for medicinal purposes. The first product, involves crushing the raw herbs and then mixing them with honey for consistency and ingesting the pellets. For the second product, the raw herbs are pulverised into a powder and ingested. Thirdly, the raw herbs are brewed into a tea and drunk. For example, tea made from chamomile flowers, steeped for more than thirty minutes in boiling water, is said to be a sedative and therefore soothes indigestion (Peter, 1995).

Herbal tea is an infusion of boiling water and herbs (fresh or dried) and it may be taken first thing in the morning, during the day and before going to bed. Each herbal tea has its own benefits and is often a remedy for mild indisposition. Many people affirm that by taking these teas over a long period, the body will build resistance to a number of illnesses. Most herbal teas are pleasant to drink and no milk is added. Honey, a squeeze of lemon, or both may be stirred into the tea (John & Rosemary, 1984). In addition, as a consequence of the resurgence in consumption of natural foods, herbal teas, which may be hot water extracts of various botanical materials, are often used as alternatives to other existing beverages.

According to du Toit & Joubert (1999), processing of honey-bush and rooibos tea includes fermentation of leaves and stems followed by sun drying and sieving. In the case of rooibos tea, steam pasteurisation of the dried products is done before packaging. This can be done indoors, outdoors or in the shade net, but it must be done quickly to retain the plants' natural oils and colour, which is so vital to quality and flavor. Oven drying has been tried in some cases but found to be less effective than natural drying in terms of preserving the natural drying oil and flavor (Peter, 1999; Anonymous, 2000).

According to Osuide (2002) and Dufresne & Farnworth (2001), the history of herbs is as old as mankind. People have used herbs for their medicinal, cosmetic and culinary needs for thousands of years. Throughout history, herbs have had their place in every civilisation in the world, with their usage changing very little as centuries passed (Dufresne & Farnworth, 2001; Osuide, 2002). Archaeologists believe that prehistoric people used herbal concoctions to treat physical complaints, long before the dawn of the written history (Osuide, 2002).

One of the most popular and enduring uses of herbs is the making of tea. Before 1750, most people lived on farms in small villages and if someone had pain, a tea of wintergreen, willow or birch, whichever grew nearby is brewed and used for treatment (Trevisanato & Kim, 2000).

Many herbal teas have a long history of use in Europe and in far east countries, and they are perceived to have many benefits (Koff, 1995). Even though herbal teas are known for their medicinal properties, it takes a knowledgeable herbalist to recommend an infusion for medicine. For certain cures the plant must be picked/ harvested at the right time and specific methods of brewing must be taken into consideration. The potency of herbal teas and hence their effectiveness cannot be predicted accurately since the concentration of active ingredients in the plant material can vary greatly. Therefore, it is highly recommended to see a herbalist for information regarding remedies for specific ailments, due to the fact that some herbal plants are more toxic than magical (Larkin, 1983).

2.3 INDIGENOUS KNOWLEDGE SYSTEM

In this study the indigenous knowledge of bush tea was examined through a survey in order to find out about the knowledge on bush tea from local people in Venda. This section will give the definition of indigenous knowledge systems (IKS) and its importance.

Grenier (1998) defined IKS as a unique, traditional, local knowledge existing within and developed around the specific conditions of women and men indigenous to a particular geographical area. McClure (1989) described the term IKS as an accumulated wisdom that has evolved from years of experience and trial and error problem solved by groups of people working to meet the challenges they face in their local environments. IKS as knowledge that is unique to a given culture and society and which is based on their common stock of experience.

Indigenous knowledge system reflects the dynamic way in which the residents of an area have come to understand themselves in relation to their natural environment and how they organize that folk knowledge of flora and fauna, cultural benefits, and history to enhance their lives (Semali & Kincheloe, 1999). According to Warren, Slikkerveer & Brokensha (1995), IKS is the information base for a society, which facilitates communication and decision-making. IKS differs from formal knowledge (scientific, western, modern, colonial) as it is deeply rooted to its environment, history and new experience and it is of epistemological nature (Mwadime, 1999).

Some authors defined IKS as the community knowledge system, communication methods and association that serves as basic for agriculture (knowledge of plants, trees, soils, insects, pests, diseases, etc.), irrigation, animal, aquaculture, food preparation and storage, engineering, ecology, environmental management, education, health care, finance, marketing and a wide range of other sustainable livelihood activities (Warren *et al*., 1995; Norman, Snyman & Cohen, 1996).

Indigenous knowledge supports a service provision mechanism that is in line with a social strategy approach. This is an approach that advocates popular participation, human development and social integration (Grenier, 1998). IKS is human life-experience in a distinct and cultural amalgamation, within a unique local and contemporary setting. The development of IKS, covering all aspects of life, including management of the natural environment, has been a matter of survival to the people who generated these systems. IKS is dynamic and holistic which means that new knowledge is continuously added. All members of a community have traditional knowledge: elder, women, men, and children (Grenier, 1998; Mwadime, 1999).

Doubleday (1993), as cited by Grenier (1998), showed that other indigenous knowledge is a source of status and income, as is the case with herbalists, and it is often jealously guarded. Another issue is that some of the indigenous people fear that their IKS will be misused, so they do not give this knowledge away (Doubleday, 1993). Specialised knowledge often belongs to a certain group of individuals, for example, male elders, midwives and traditional healers (Grenier, 1998). There is an argument on IKS and science, where some people say IKS is more than science but the two intersect in certain subject areas such as technology, resource management, ecology and classification of living organisms. Agrawal (1996) stated that the critical difference between IKS and scientific knowledge lies in their relationship to power and that it is not the holders of indigenous knowledge who exercise the power to marginalize.

All knowledge systems have their limitations and weaknesses and IKS is no exception. That is why it needs to be complemented by conventional western oriented scientific methods and ideas. Neither IKS nor international science will be appropriate and accurate in all circumstances. IKS can be less precise, as international science can measure or statistically verify phenomenon to a higher level of precision (McCorkle, 1989; Mwadime, 1999). Techniques for collecting IKS should document what people do and why, within the larger framework of what they know and think (Brookfield, 1996). Granier (1998) reported that IKS includes learning systems, which involves the indigenous methods of imparting knowledge, indigenous approaches to innovation and experimentation, indigenous games and indigenous specialists.

A first step in developing a medicinal plant resource is the creation of a medicinal plant database. A core of the database is an inventory of all the plants that are known to have been used, or which are still used as medicine in that country (Gericke, 1996). A great deal of folk knowledge and scientific information is available on medicinal plants in South Africa, but it has been extremely difficult to access the information as it is scattered throughout scientific literature (Gericke, 1996; Green, 1996). Knowledge of traditional healers already exists in large volumes on medicinal and poisonous plants of southern and eastern Africa (Watt & Breyer-Brandwijk, 1962; Gericke, 1996).

Most important in the evaluation of herbal medicine, is the long history of folk-use, without known severe side effects or toxicity and no known toxic chemistry. A detailed history of safe folk-use for a particular medicinal or cultural condition is essential to promote and develop medicinal plants. A critical examination of South Africa's records of the folk-usage of medicinal plants reveals that a great deal of information has been inadequately recorded and a considerable additional effort is needed to gather information in sufficient detail to be of real scientific value (Gericke, 1996). According to Gericke (1996), there is no doubt that there are some group of plants which are regarded as secrets, so the indigenous healers participating in each and every project must be given a clear indication or idea on what the research is intended to do with their knowledge, and must be asked if data can be made available to other researches or to the industry.

2.4 GREENHOUSE PRODUCTION

2.4.1 Greenhouses

One of the aims of this study was to investigate the growth and yield of bush tea under a plastic covered greenhouse.

Greenhouses have a long history of use by horticulturists as a means of forcing more rapid growth in plants (Hartmann, Kester, Davies & Geneve, 1997). A greenhouse is one of the structures in which temperature and light could be controlled, where seeds can germinate, cuttings rooted or tissue culture micro-plants rooted and acclimatised (Hartmann *et al.*, 1997). The purpose of a greenhouse is to create an internal climate that is more favourable to the plants growth than on the outside environment. As a result of the cost of a greenhouse, the area under protection is used intensively, using high planting densities and labor-intensive cultivation practices. However, high planting densities create an environment around plants with high humidity as the leaf canopy may restrict circulation (Niederwieser, 2001). Greenhouse container plant production needs frequent fertigation, which is the continuous supply of fertilizer in the irrigation water (Ku & Hershey, 1996).

Different types of greenhouses are being used in South Africa of which the shade net and plastic houses /tunnels are the most popular (Niederwieser, 2001). The designs of plastic tunnels and the type of covering material have advanced during the past few years in South Africa. The pad and fan method of cooling and ventilation is probably the most effective in South Africa (Niederwieser, 2001). Greenhouses are used to increase the humidity, increase the temperature during winter, decrease daily maximum temperature during hot summer days, decrease the diurnal variation in daily temperature and decrease the amount of UV light (Niederwieser, 2001). This gave us reason to choose a specific greenhouse in our trial when we used a poly-ethylene plastic covered tunnel (88% light penetration through plastic), which is economical and practical for small-scale farmers.

2.4.2 Growing media

Growing media is any material or a combination of materials used to provide water and nutrient retention, and permit gas exchange as well as to provide support for plant growth. Growing media can also anchor the plant and control the microflora. Greenhouse growing media have chemical and physical properties that make them distinctly different from field soils (Lemaire, 1995; Ball, 1998).

In this study, we experimented with pine bark and sand as our growing media. These two growing media were selected because they were readily available (pine bark for instance, is a waste product of the South African Forestry Industry), and both growing media are substantially cheaper than imported peat. Small-scale farmers, at a low cost, could easily use these growing media. However, container production with pine bark and sand requires some cultural practices such as irrigation and fertilization, which are also applicable to other media like peat.

The growing medium chosen should have certain characteristics, namely suitable physical and chemical properties, available in significant quantities, uniform and affordable. Chemical properties include pH, soluble salt, cation exchange capacity, while physical properties include bulk density, total porosity, air space, available water holding capacity and moisture content (Ball, 1998). In growing media, such as pine bark and sand, the concentration of essential nutrients around the roots, which is critical to plant growth, depends upon the media's moisture holding capacity. With a given amount of nutrients in a container with a growing medium, the nutrient concentration around the roots decreases as the moisture content increases (Ball, 1998).

When the chosen growing medium has a low water-holding capacity or cation exchange capacity, amendments should be made which will improve water and nutrient retention (Boodley, 1998). However, the pH of the growing media should also be taken into consideration and a growing medium with a high pH should be avoided as lowering the pH is more difficult than raising it. If the growing medium is poorly aerated and drained, soil amendments, which improve the previously mentioned conditions, should be considered (Ball, 1998; Boodley, 1998). In addition, the choice of a substrate must be realised according to its physical, biological and chemical properties and according to the fertilization supply techniques (nutrient-solution, slow-release fertilizer) and irrigation techniques (dripping, sprinkling) (Ball, 1998; Boodley, 1998). As mentioned before, the two growing media (sand and bark) were selected and will therefore be described.

Sand media consists of small rock particles ranging from 0.05 to 2.0 mm in diameter, contains virtually no mineral nutrients and has no buffering capacity or cation exchange capacity (CEC) (Handreck & Black, 2005). Coarse concrete-grade sand is mostly used and its advantage is that it has good drainage and aeration properties (Hartmann *et al.*, 1997; Fourie, 1999). Sand has a high water holding capacity, low in cost (it is re-usable), low structure loss over time and heavy in weight that gives stability. Disadvantages of sand include the low air filled porosity and beach sand is contaminated with high salt levels, the bulk density is high, and it is not sterilized when purchased. Sand normally has a pH of 7.2 (Ball, 1998; Boodley, 1998; Fourie & Hattingh, 1999).

Pine bark (waste product from sawmills) was regarded as a waste product until the 1950's. At present it is used in the nursery industry and has become a major component of most growing media in South Africa (Holcroft & Laing, 1995). Because of its relatively low cost, light weight and availability, bark is very popular and used widely in mixes for propagation and for container grown plants (Hartmann *et al.*, 1997; Fourie & Hattingh, 1999). Bark contains various organic compounds. Organic compounds such as phenolics and tannins, which are biologically active at low concentrations, may reduce plant growth. Composted pine bark has been shown to contain actinomycetes, which produce antibiotics such as actinomycin and musarin and *Trichoderma spp*., which produce gliotoxin and viridin. These have been found to be effective against many pathogens (Ansermino, Holcroft & Levin, 1995; Reis, Solivia & Martirez, 1995).

According to Ansermino *et al.* (1995), when pine bark was compared to peat, it was confirmed that pine bark had a lower water holding capacity than peat, so it requires more irrigation but it has better drainage properties. The authors reported that pine bark does not appear to be deficient in any element except possibly iron and copper. Micronutrients such as manganese can occur in toxic concentrations and cause other nutrient imbalances in pine bark growing medium (Sant, Selmer-oslsen, Gislerod & Solbraa, 1984; Wilson, 1983).

Bark does not have enough water holding capacity unless it is very decomposed, but its water holding capacity can be increased by adding various materials, e.g. peat, perlite, vermiculite, etc. (Wilson, 1981; Ansermino *et al.,* 1995). However, with an experiment done by Ansermino *et al.* (1995), comparing peat and pine bark as media for bedding plants, composted pine bark gave superior flowering in impatiens plants as compared to plants grown in peat.

2.4.3 Fertigation

Fertigation is defined as a method of applying fertilizer in irrigation water, either in an open or closed system (Nestby, 1998; Dalvi, Tiwari, Pawade & Phirke, 1999). Fertigation is the most effective method for feeding plants than other conventional methods (Janat & Somi, 2001). Fertilizer and irrigation methods are the key factors for yield increase and yield quality improvement of any plant, thus choosing the right method is essential. The use of fertilizers through irrigation is more common nowadays, as it makes it possible to fertilize at the right time, with the right concentration and amount to the plant (Hipps, 1993; Nestby, 1998). In this study, automated drip fertigation was used for the trial and this system will be described.

Fertigation is an effective method due to minimal loss of water and nutrients, and it minimizes the use of soil as storage reservoir for nutrients and water, thus improving yield and water-use efficiency (Janat & Somi, 2001). The most common nutrient applied by fertigation is nitrogen. Other nutrient which includes phosphorus, potassium, sulphur, zinc and iron (Follet, 2002) can also be applied through fertigation. A few problems that may occur with fertigation are the build up of excess soluble salts in the media. This, however, only occurs when there is excess fertilizer, poor drainage, insufficient water and poor quality water (Ku & Hershey, 1996).

For the greenhouse tunnel experiment, bush tea was grown under a drip fertigation system. Drip irrigation system was selected due to the fact that it has the potential to improve nutrient management and increase farm profit by optimizing plant growth, thus resulting in higher yield and better quality. Drip irrigation is thus a user friendly irrigation system, which is commonly used in agriculture. Water is applied through a drip tube and emitted in limited quantities to the root system (Ball, 1998; Nestby, 1998). This method of fertigation therefore ensures that applied soluble plant nutrients are available to the plant's root system (Nestby 1998, Mmolawa & Dani, 2000). According to Cooke (1982) and Janat & Somi (2001), this method was also found to be a more effective method of applying water and soluble nutrients. With conventional methods such as broadcasting of fertilizer, reliance is made on rainfall or sprinkler irrigation to take the fertilizer down to the roots. Dry weather and no irrigation often result in delayed movement of fertilizers to roots or if the rainfall is too heavy, more of the fertilizers end up in the drains. To overcome this problem, it has been necessary to go for better methods to make fertilizers accessible to the plant through drip fertigation.

In an open field with a drip fertigation system, water and nutrients go directly to the trees and not to the weeds, while transport of fertilizers off-site is reduced. In fact, drip irrigation system often functions best on dry, sandy sites (Janat & Somi, 2001; Follet, 2002).

To obtain healthy plants, plant growth generally depends on adequate availability of water, mineral nutrients and oxygen in the rhizospheres. Irrigation frequency and total volume of water applied to the plant therefore influence plant performance, nutrient management in the root zone, and the amount of fertilizer lost through leaching (Southwick, Rupert, Yeager, Lampinen, De Jong, & Weis, 1999). In addition, irrigation schedules should be based on plant growth status and solar radiation (Larson, 1992). Plants growing at a faster rate under high light intensity and leaf temperature require more water (Davidson, Mecklenburg & Peterson, 1988). Plant growth can be retarded by an insufficient amount of water, but it is generally not adversely affected by excessive irrigation if the growing media is well drained (Janat & Somi, 2001). From the experiments done by Buwald & Kim (1994) on the effects of irrigation frequency on root formation and shoot development of spray chrysanthemum cuttings, it was also shown that a high irrigation frequency had little influence on the growth of cuttings during the root initiation phase. Cuttings that were subjected to a lower irrigation frequency accumulated more dry matter and contained higher carbohydrate levels at final harvest than cuttings that were more frequently irrigated.

It is clear that by regulating the water frequency, one could overcome limitations on plant growth. One could also add that conventional irrigation tends to lose more water, unlike using drip fertigation, thus some measures should be taken into account to persuade farmers to switch from conventional irrigation method to drip fertigation.

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CHAPTER 3

INDIGENOUS KNOWLEDGE OF *ATHRIXIA PHYLICOIDES* FROM LOCAL PEOPLE IN VENDA

Abstract

A survey was conducted in selected villages around Thohoyandou and Nzhelele in Venda, Limpopo Province of South Africa by means of personal interviews to gather indigenous knowledge and validate the uses of bush tea plants from the local people. The interviews involved three types of respondents, viz traditional healers, street sellers and bearers of indigenous knowledge (people who have knowledge of the plant and how it works and they were not traditional healers nor street sellers). A total of one hundred respondents were interviewed. An important finding of the study was that people from the area of study posses a remarkable knowledge of the plant identity. Bush tea is used as a medicine, health tea as well as for making traditional brooms. Bush tea is used to treat a wide range of physical aliments. Some physical aliments that could be treated using bush tea were headache, stomachache, influenza and leg wounds. The infusion of the plant is known to have aphrodisiac properties and it can also be used to cleanse the womb, kidneys, and veins. It is also used to purify blood. The results showed that the plant was harvested in different ways depending on the reason of harvesting. Furthermore, the information obtained revealed that bush tea was used in combination with other medicinal plants and that people from the area of study still depend on plants for traditional medicine.

3.1 INTRODUCTION

Indigenous knowledge system (IKS) refers to the complex set of knowledge and technologies existing and developed around specific conditions of populations and communities indigenous to a particular geographical area. IKS can also develop within communities descended from populations that inhabited the country at the time of conquest or colonization (Warren *et al.*, 1995; Grenier, 1998). Indigenous knowledge is local knowledge unique to a given culture or society. These populations - irrespective of their legal status - retain some of, or their entire own social, economic, cultural and political institutions (Grenier, 1998; Mwadime, 1999).

South Africa has an extremely rich biodiversity that is yet to be fully understood. Some of this understanding is to be found in the indigenous knowledge system that relates to the treatment of diseases through connections with spirituality and the science of herbs and plants on the one hand, and animal products on the other hand. Research activity should center on indigenous medicine and pharmacology, encompassing human health and indigenous medicine (Warren *et al.*, 1995). However, the problem is that indigenous people fear that their indigenous knowledge will be misused, so they keep quiet about it (Doubleday, 1993). Some knowledge is the source of status and income as is the case with herbalists and is often therefore jealously guarded (Grenier,1998).

Indigenous knowledge (IK) is more than just a science, but the two intersect in certain subject areas, such as technology, resource management, ecology and the classification of living organisms (Agrawal, 1996). Agrawal (1996) stated that the critical difference between indigenous and scientific knowledge lies in their relationship to power. Indigenous knowledge is often contrasted with modern knowledge development at the university, research institutions and private firms by using a formal scientific approach. We need to understand IK and its role in community life from an integrated perspective that includes both spiritual and material aspects of a society, as well as the complex relation between them (Warren *et al.*, 1995).

Efforts should be made to document the medicinal use of plants before much of this is lost. Unfortunately, at present, the ethnobotanical knowledge is in danger of being lost in the country, due to changes in land use via urbanisation, which destroy much of the habitat of the useful plants. This can also be because of the elder traditional healers that pass away without handing down the knowledge. The loss of traditional medicinal knowledge in culture that is undergoing a rapid change is as irreversible as the loss of plant species (Joshi and Joshi, 2000).

A survey was conducted in twenty-five villages in Venda with the objective of documenting indigenous knowledge held on bush tea (*Athrixia phylicoides*) by the local population. Bush tea is one of the herbal tea medicines, which has been used locally in people's daily lives. Due to over-harvesting by the users, the plant could face danger of extinction. So it is important to collect and document the knowledge on this plant from the local people to prevent the above mentioned concerns.

3.2 MATERIALS AND METHODS

A field survey was conducted from 31 March until 19 April 2003 in twenty-five different villages in Venda (Limpopo Province of South Africa). The survey was conducted by means of verbal interviews. Hundred (100) respondents were interviewed in the 25 villages. Interviews were performed with the following respondents: traditional healers, street sellers and bearers of indigenous knowledge. For the interviews, a questionnaire was developed and used, which contained questions such as traditional knowledge of bush tea plant, propagation information, marketing, harvesting, post-harvest handling and methods for tea and medicine preparation (See Appendix 1, p. 91)

3.3 RESULTS AND DISCUSSION

3.3.1 Respondents profile

Thirty-one percent of the respondents were traditional healers, 25% were street sellers and 44% were bearers of indigenous knowledge (Fig. 3.1). The respondents were mainly females.

Twenty-six percent of respondents were younger than 40 years of age, whereas 74% were older than 40 (forty). Twenty-nine percent of the respondents never went to school.

Of those who went to school, 58% complicated grade 1 to grade 7, 38% had grade 8 to grade 12, while the rest (4%) had tertiary education. From the sampling that was made females knew more about the plant. It could be because women are more associated with the forest than men. One more reason could be that females were the majority of the respondents compared to male.

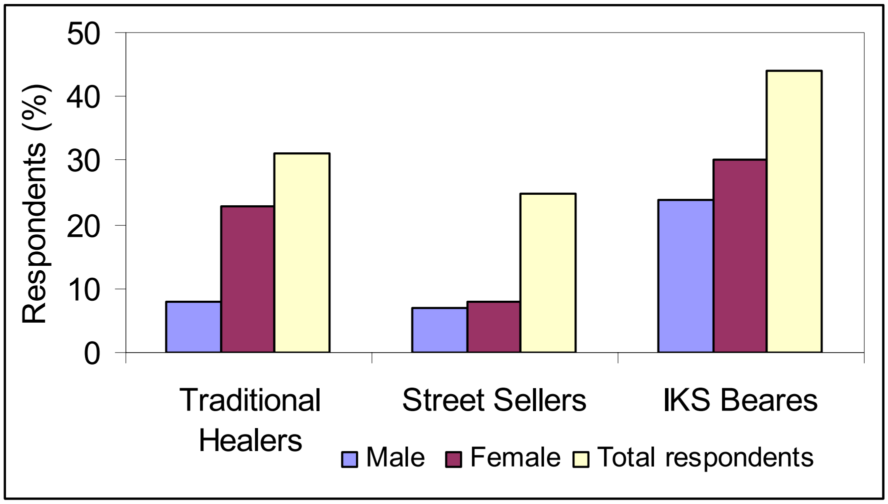

Figure 3.1 Distribution of respondents by job description and gender

Figure 3.2 Traditional brooms made from bush tea being sold in a street market (Shackleton, 2004)

3.3.2. Traditional knowledge on bush tea

Majority of the respondents knew the plant very well and is locally known as *bostee* (bush tea). One important finding of this study was that people from the study area posses a remarkable knowledge of the plant identity and its uses to treat a wide range of physical ailments. They also had indigenous knowledge about the uses of other medicinal plants. Eighty-five percent of the respondents used or sold the plant and only 15% of the respondents did not use or sell the plant at all. Most of the respondents (85%) knew the plant as bostee (bush tea), while others knew it as swanzwo (4%), mutsheke (4%), muthathalilwo (2%), mutshutshungwa (4%) or as thanzwamuvhili (1%). Ninety-nine percent of the respondents indicated that they obtained the plant from the veld (natural habitat) and the rest obtained the plant from previously cultivated fields (Fig. 3.3 and 3.4).

Figure 3.3 Bush teas harvested for making brooms from the veld (natural habitat) (Photo taken by Prof. Jana Olivier)

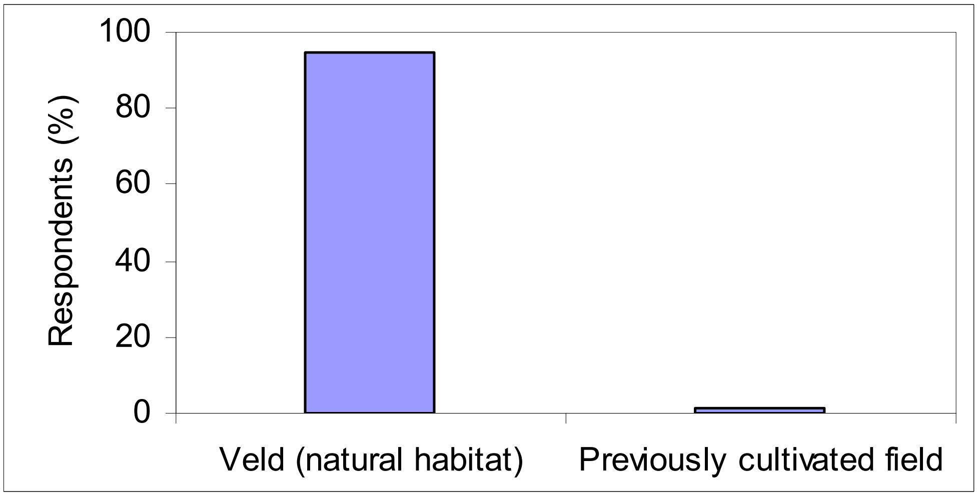

Figure 3.4 Percentages of respondents (%) indicating where they source bush tea

Forty percent of the respondents used the plant for tea, 31% used it for medicine, while 29% of the respondents indicated that they used the plant for making traditional brooms (Fig. 3.5).

A question was raised as to which plant part was used for medicine. Majority (44%) of the respondents indicated that they preferred to use the leaves, 35% used the stems, 11% used the roots and the minority (10 %) used the whole plant (Table 3.1).

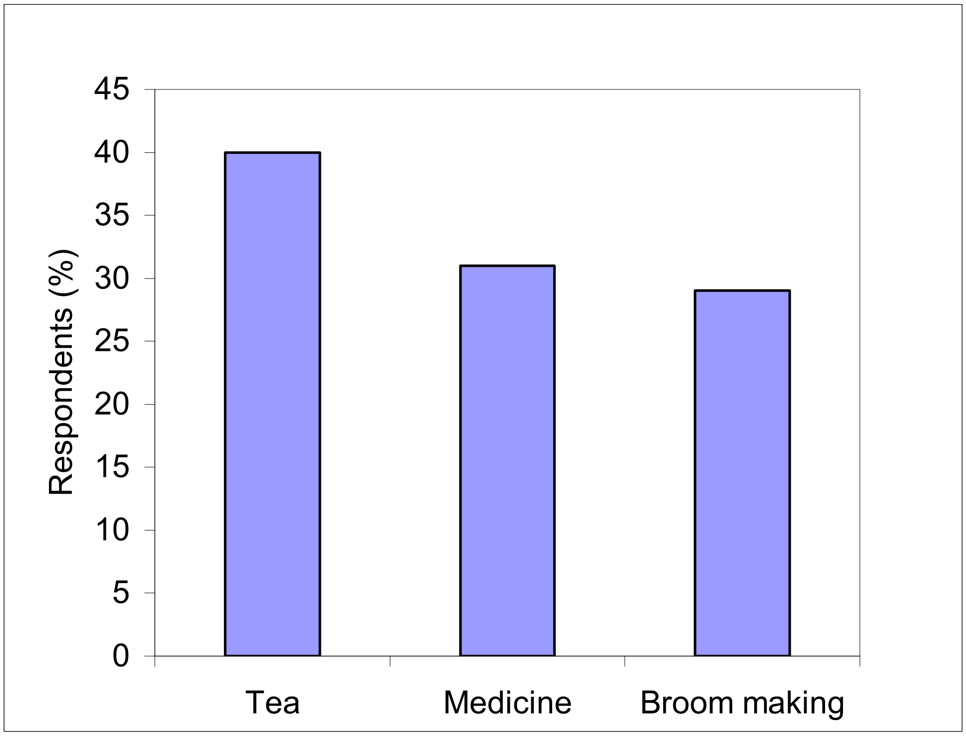

Figure 3.5 Three different uses of bush tea plant as indicated by the respondents

Table 3.1 Different plant parts of bush tea plant as used by the respondents

PLANT PART USED	RESPONDENTS (%)
Leaves	44
Stems	35
Roots	11
Whole plant	10

3.3.3 Propagation information on bush tea

Eleven percent of the respondents grew the plant for themselves. Twenty-five percentages indicated that they did not grow the plant, but they were interested in growing it for themselves. The rest of the respondents (64%) showed no interest in growing the plant. When asked on how they propagated the plant, 24% of the respondents indicated that they used the roots to propagate the plant, 1% used cuttings, 4% used seeds and the rest (71%) did not propagate the plant (Fig. 3.6). One can now understand the concern for over-harvesting. The survey indicated that the majority of the respondents had no interest in propagating the plant for themselves. One reason they mentioned for was that the plant was easily available from the wild and the lack of interest.

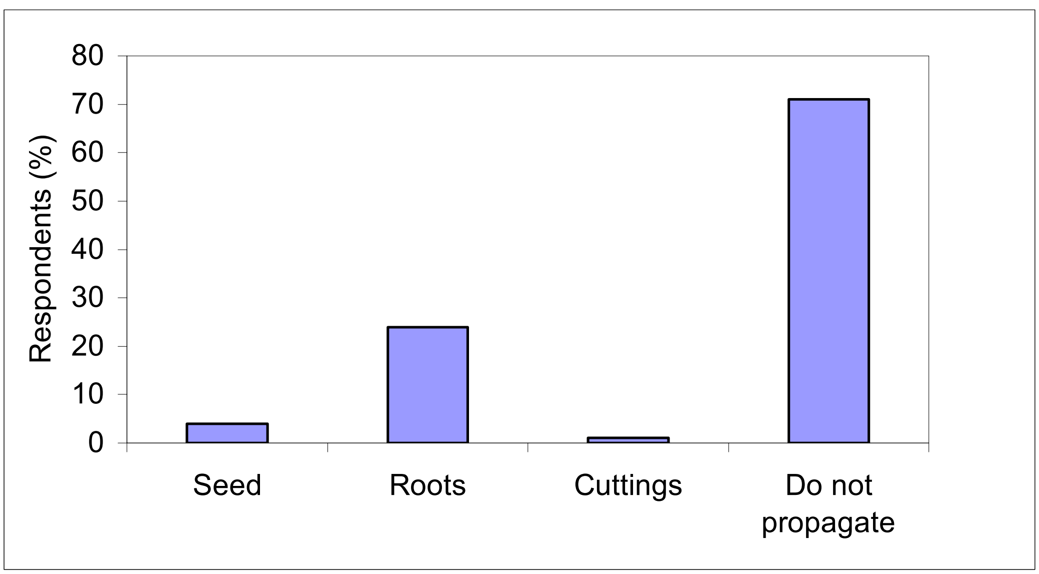

Figure 3.6 Plant parts used to propagate bush tea

When the respondents were asked whether they would like to buy the plant, 29% of them were interested in buying the plant, provided it was grown for them. However, 71% showed no interest in buying the plant. One reasons for lack of interested was because bush tea plants are abundant in Venda. Nevertheless, when asked if they could grow the plant for themselves, only 43% of the respondents showed an interest in growing the plant, provided they could be shown how to. Majority (57%) of the respondents showed no interest in growing the plant for themselves. Majority of the respondents who were not interested in cultivating were IKS bearer (Fig. 3.7). When comparing traditional healers with the street sellers, traditional healers were a little bit more interested in cultivating the plant than street sellers (Fig. 3.7).

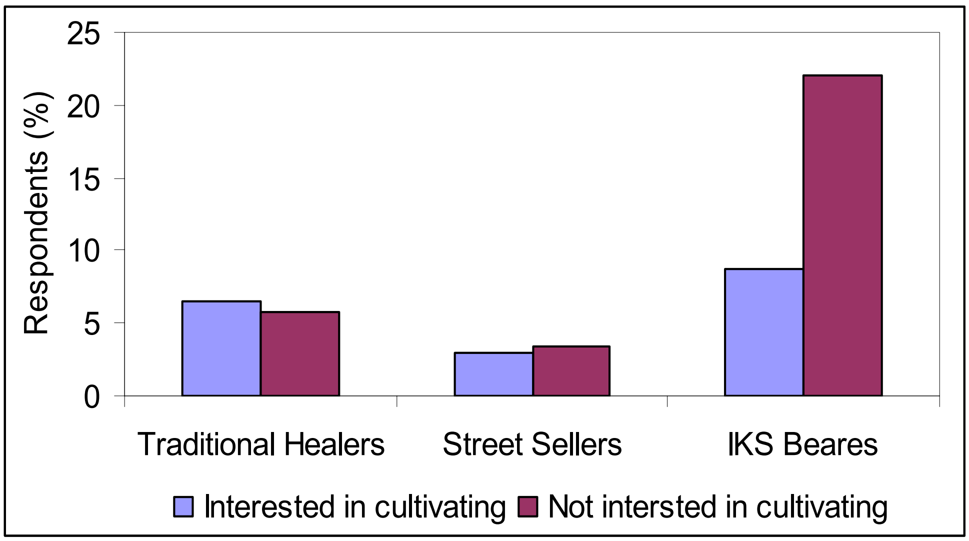

Figure 3.7 Percentages of respondents who indicated an interest in cultivating bush tea

3.3.4 Harvesting and post-harvest handling

Methods of harvesting the plant depended on the purpose as well as required plant part. Thirty-five percent of the respondents indicated that they cut the whole plant (for medicine and for broom making). Eighteen percent of the respondents uprooted the plant (when they wanted to use the roots as well as above growth for medicinal purposes). Forty-seven percent of the respondents cut the leaves and branches when harvesting for tea and medicine (Fig. 3.8).

Figure 3.8 Methods of harvesting bush tea plant

The plant is harvested in different ways depending on the reason for harvesting. Ways of harvesting included cutting the plant either from the stem or the branches, as well as uprooting the whole plant. If the respondent wanted to use the plant for medicinal purposes, he or she uprooted the plant, in order to use the roots as well. When harvesting for making tea, they cut the leaves and twigs and lastly for broom making purposes, they cut off the whole plant. As it was indicated that ninety percent of the respondents indicated that they obtained the plant from the veld, when asked what type of area of the veld (natural habitat) they harvested the plant from, 49% of the respondents indicated that they harvested the plant on the mountains, while 47% of the respondents harvested the plant from hills. Only 4% of the respondents indicated that they harvested the plant from open cultivated fields (non- commercial fields) (Fig. 3.9).

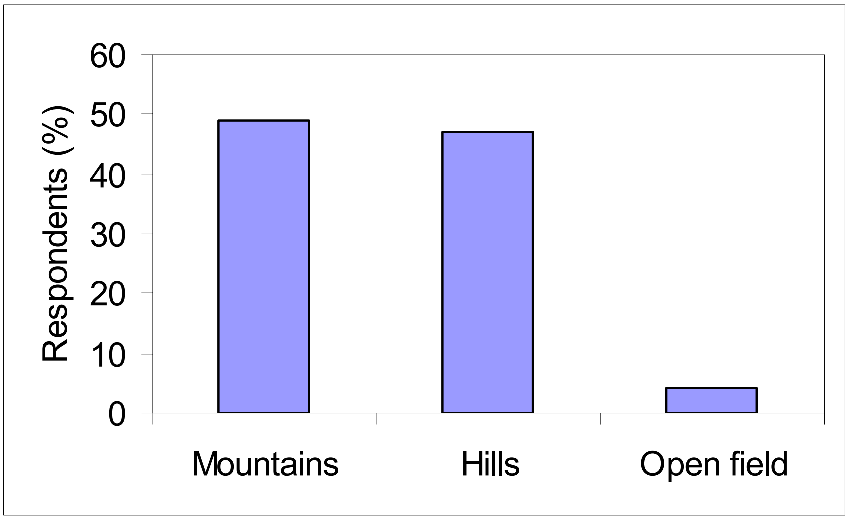

Figure 3.9 Areas where bush tea plant is harvested

Majority of the respondents (90%) travelled less than five kilometers and the rest of the respondents (10%) travelled from 6 to 45 km to harvest the plant. Of those who travelled to harvest bush tea, 11% paid transport cost, while the rest (89%) did not pay any transport cost to obtain the plant. The distance travelled to obtain bush tea determined how much respondents paid per trip. The cost varied from as little as R2 per trip to as much as R14 per trip.

A majority of the respondents (62%) indicated that the right time to harvest the plant for broom making was after flowering, while 20% indicated that they harvested the plant before flowering. Another 28% of these respondents indicated that to them it did not make any difference either to harvest the plant before or after flowering for making traditional brooms (Fig. 3.10). Stems together with shoots were dried first and then tied up to make brooms.

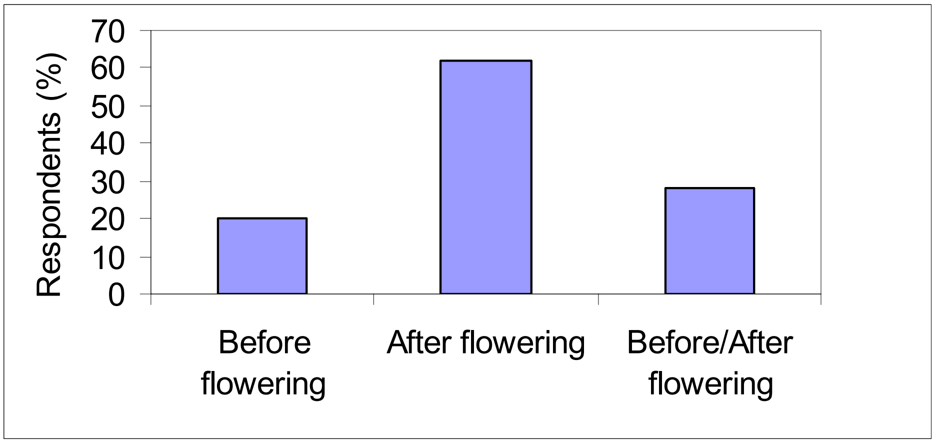

Figure 3.10 Indication of time to harvest bush tea for broom making

The results from the survey indicated that there was a risk in terms of the survival of these plants, since these plants may not be given a chance to develop seed for future generation. Looking at the way in which the respondents harvested this medicinal plant, there is no doubt that the plant is in danger of over-harvesting and exploitation. Respondents had no limits to accessing this particular plant.

3.3.5 Marketing

The respondents were asked if they sold bush tea to people as a medicinal plant. Fifty-two percent of the respondents indicated that they do not sell bush tea to people. Thirteen percent of the total number of respondents who sold bush tea as medicine was traditional healers and being the highest percentages as compared to five percent for both street sellers and IKS bearers (Fig. 3.11).

Figure 3.11 Percentages of respondents who sold the bush tea plant as medicine

Of those who sold the plant, 52% indicated that they never sold the plant, while 48% of them indicated that they sold the plant regularly (Fig. 3.12).

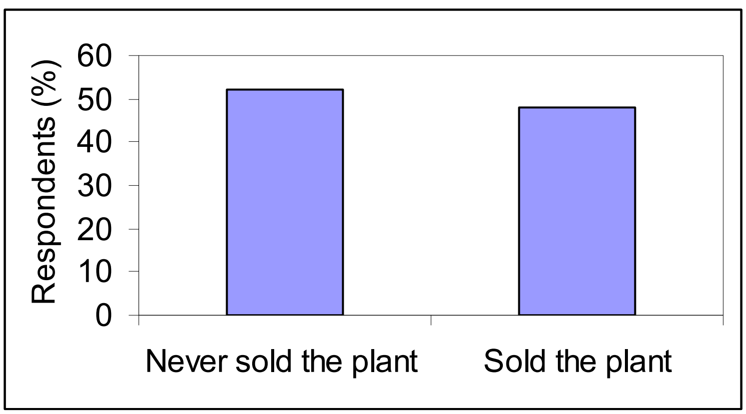

Figure 3.12 Indication on whether respondents sold bush tea and how often they sold it to the people

The reason why others did not sell bush tea plant was mostly because the plant was well known to patients and they could give only prescription and instructed them on how to harvest and prepare it. Another reason was that there are other plants that are equally effective to use as medicine for that specific ailment.

These results were in agreement with Watt & Breyer-Brandwijk (1962), Roberts (1990), Hutching, Scott, Lewis, & Cunningham (1996) and Swanepoel (1997), where different ethnic groups used the plant (bush tea) for medicine, tea or broom making. Majority of respondents indicated that they sold the plant to different groups of people. Thirty-six percent of the respondents sold the plant to Vendas, 33% sold the plant to Shangaans, 13% to Whites, while 18% of the respondents sold bush tea to different ethnic groups like Sotho's, Pedis, Ndebeles and others.

The respondents also listed the most important types of plant that they use for medicine besides bush tea, and as follows *mukuvhawivhi* (*Elaeodendron transvaaliensis*), mupesu (*Securanda longependunculata*), munnamutsu (*Artabotrys monteiroae*), muthathavhanna (*Heteromorpha trifoliate*), murumelelwa (*Pleurostylia capensis)*, ndilela (*Conostornium natalense*), mupeta (*Osyris lanceolata*), thudugwane (*Hypoxis hemerocallidea*) and others.

Seventy-five percent of the respondents indicated that bush tea was extremely effective to treat heart diseases, diabetes and high blood pressure. However, 19% of the respondents indicated that the plant was slightly effective in treating the above-mentioned diseases, while 6% of them indicated that the plant was ineffective in treating heart diseases, diabetes and high blood pressure. According to van Wyk (2000), it is believed that the bush tea plant in Venda has aphrodisiac properties. In this case, the respondents confirmed that it does have aphrodisiac properties

There are various diseases that could be cured by bush tea plant besides the ones mentioned above. They also showed that the infusion of this plant could also be used to cleanse the stomach (stomachache), for headache and or used to add and purify blood. The respondents also mentioned that the infusion of this plant was used to cleanse the veins, kidneys and the womb. These results were also confirmed by findings of Watt & Breyer-Brandwijk (1962), Roberts (1990), Hutching, Scott, Lewis, & Cunningham (1996) and Swanepoel (1997).

For medicinal purposes, when asked whether there were plants that could work the same as bush tea (*Athrixia phylicoides),* majority (69%) of the respondents knew other plants that worked the same. According to them, several plants have been used as a substitute for bush tea plant, namely mutangule, *Securanda longependunculata* (aphrodisiac); *Hypoxis hemerocallidea* (aphrodisiac or for high blood pressure); *Artabotrys monteiroae* and *Elaeodendron transvaaliensis* (to cleanse the stomach, veins and blood); *Eucalyptus sp.* (for headache and influenza) and many other plants.

3.3.6 Tea and medicine preparation

The plant could be used either fresh or dried for tea and medicinal purposes. According to Mabogo (1990) and Swanepoel (1997), an extract from soaked roots and leaves are taken by the Vha-Venda as a medicine. The respondents also indicated that dried or fresh leaves (including the twigs) are boiled and the extract is drunk with sugar as a tea. The bush tea plant could be used right after harvest and also after it had been stored or dried.

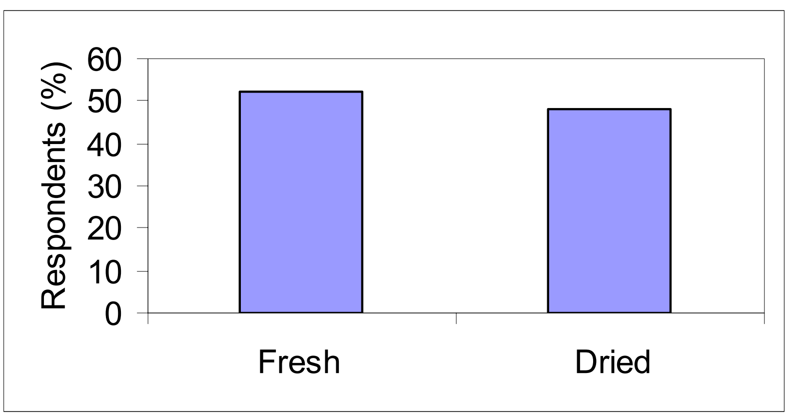

Figure 3.13 Fresh and dry plant materials of bush tea used for medicine

Fifty-two percent of the respondents stored the plant for medicinal purposes, while 48% of the respondents did not store the plant for medicinal purposes (Fig. 3.13). It was interesting to note that the IKS bearers were able to store the plant before use. Unexpectedly, the traditional healers had higher percentages of not storing the bush tea before use (Fig. 3.14).

Figure 3.14 Indication of whether respondents stored bush tea or not before usage

When the question was raised as to whether something is added when preparing medicine or tea, 19% of the respondents indicated that they mixed other plants in order to make medicine. For example, they added mukuvhazwivhi (*Elaeodendron transvaaliensis)* and ndilela (*Conostornium natalense*) to boost the plant (to cleanse the stomach and for aphrodisiac purposes). However, bush tea could also be mixed with other plants for medicine. Eighty-one percent of the respondents did not add anything to the medicine, but use the plant as it was. When preparing the tea, all of the respondents indicated that they boiled the leaves, including the twigs, which is not done with other teas (Mabogo, 1990).

Depending on how strong the people wanted the tea to be, respondents indicated different durations for boiling the leaves. Most of the respondents (85%) estimated the time to be from 3 to 10 minutes, while the rest indicated that the tea could be boiled for more than 12 minutes. When it is boiled for a specific medicinal reason, it could be boiled for 3 hours and even more than that. Similar to black tea, bush tea could be taken with either milk or sugar or both. Majority of the respondents (95%) indicated that they added something when making the tea, and the rest indicated that they boiled the tea and just drink it. Forty-eight percent of the respondents added only sugar when they prepared the tea, and 49% of respondents added only milk in the tea. Surprisingly, 3%

of the respondents also added lemon, honey and other teas when they made tea for the flavor.

3.4 CONCLUSIONS

Bush tea is well known by the people in Venda as *bostee*. People who knew more about bush tea were females. It could be because women are more associated with the forest than men. Leaves of bush tea are mostly used for medicine and tea purpose. Bush tea is easily available to the users. Judging by the way in which this people harvested the plant, it is obvious that the plant is in danger of over harvesting and exploitation.

Judging by the keen response of different respondents, this plant will always play an important role in their lives. Efforts should, therefore, be made to document useful plants species and conserve ethnobotanical knowledge and practices that available. The ethnobotanical knowledge is in danger of being lost in the country due to urbanization. Many plant habitats are being destroyed, and the older traditional healers pass away without handing down their knowledge.

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CHAPTER 4

EFFECT OF FERTIGATION FREQUENCY AND GROWING MEDIUM ON THE GROWTH AND YIELD OF *ATHRIXIA PHYLICOIDES*

Abstract

The effects of growing medium (pine bark and sand) and fertigation frequency (0.4 ℓ/day, 1ℓ /day, 2 ℓ/day, 2 ℓ/2nd day and 2 ℓ/ week) on growth and yield of bush tea were studied. Growing medium and fertigation frequency significantly affected the growth performance and yield of bush tea. Sand grown plants grew dramatically from an initial height of 15.7 cm to a height of 1.08 m at 180 days after planting (DAP) (winter and spring). These plants also produced a significantly higher total fresh and dry mass compared to those of pine bark plants in both seasons at 90 and 180 DAP. Stem diameter of bush tea was unaffected by the different growing media and fertigation frequencies. Greater number of stems and shoots were observed in sand grown plants compared to pine bark grown plants. Sand grown plants produced a higher root mass than those of pine bark grown plants over both seasons, with significant differences in winter season results. Plants grown in sand had significantly longer roots ($P \leq 0,05$) than plants grown in pine bark at 90 DAP. However, at 180 DAP the differences in root lengths were no longer significant. Sand grown plants also produced more flowers than pine bark grown plants.

Fertigation frequencies caused significant differences in growth performance and yield of bush tea. Plants fertigated with 1 ℓ/day were significantly taller, followed by plants fertigated with 0.4 ℓ/day, 2 ℓ/day, 2 ℓ/2nd day and 2 ℓ/ week in that order. In addition, fertigation frequency of 1 ℓ/day resulted in plants with greater stem and leaf fresh and dry mass. Fertigation frequency of 2 ℓ/day was found to be too high and probably reduced oxygen supply to the roots and consequently retarded above plant growth. Overall, plants grown in sand media had superior stem and shoot mass, leaf mass, root mass and flower mass compared to plants grown in pine bark. Plants that received insufficient amount of water (2 ℓ /week) resulted in stunted growth and produced the

least yield. In conclusion, bush tea plants performed better in sand growth media than in pine bark growth media. An application rate of 1 ℓ/day was ideal for growth and performance of bush tea as the plant performed better under this fertigation frequency.

4.1 INTRODUCTION

In South Africa, a large part of the day-to-day medicine is still derived from plants and large volumes of plants or plant extracts are sold in the informal and commercial sector of the economy (Manzini, 2005). It has been estimated that about 12 to 15 million South Africans still depend on traditional herbal medicine from 700 indigenous plant species (Afolayan, 1996; Swanepoel, 1997). The demand for medicinal plants increases as the population grows. Due to this demand, many populations of wild medicinal plants are under pressure of becoming diminished. Bush tea is one of the medicinal plants that are harvested regularly. In this chapter, the cultivation of bush tea under a tunnel, including the effects of fertigation frequency and growing medium on the growth performance will be described.

The cultivation of medicinal plants is the most recent branch of agriculture and horticulture. Cultivation conditions differ from a plant’s native habitat and may, therefore, result in changes in the chemical yield and growth and flowering habit (Máthé, 1988). Greenhouses have the potential of modifying and creating an ideal protected microclimate, in which high quality plants could be produced (Manzini, 2005). The growth performance of plants is closely linked to the environment in which they grow (Máthé, 1988). According to Nichols (1989), most of the medicinal plants grow pre-dominantly vegetatively in the early stages of development. Thus, plants should produce mainly leaves not flowers when young. Therefore, temperature management becomes critical and with the aid of a controlled environment, such as found in a greenhouse or shade net, the required temperature regime can be achieved (Manzini, 2005). Fertigation system is the critical mechanism for improvement of yield and quality of crops under cultivation (Janat & Somi, 2001). Fertigation refers to the application of nutrients through an irrigation system. Nitrogen is the most frequently applied nutrient where as P, K, S, Zn and Fe are less applied (Follet, 2002). Drip irrigation system is a much more precise fertigation method that is used to deliver nutrients to the roots, where they can be effectively utilized (Southwick *et al.*, 1999).

According to Nestby (1998) drip fertigation is the best method as a fertigation system, in which the accurate amount of water and fertilizer are applied in time. It can result in water savings if the correct management procedures are applied (Harz, 1993). The advantage of water savings by drip is forfeited if the crop is over irrigated (Hillel, 1987).

A good hydroponic medium should support, not break down the plants in the system, absorb and retain moisture, be porous to allow air circulation and have proper drainage, and protect plant roots from temperature extremes. Different growing media are suitable for different crops (Niederwieser, 2001). The choice of a substrate must be realised according to its physical, biological and chemical properties and also according to the fertilization supply techniques (nutrient-solution, slow-release fertilizer) and irrigation techniques (dripping, sprinkling) (Lemaire, 1995; Ball, 1998). The two growing media for this study, pine bark and sand were used since they are readily available to small scale farmers.

There is no information available on growth and yield of bush tea under an open-hydroponic system under a closed environment system. The open-hydroponic system is used for the production of plants in a soil-based media such as sand and pine bark. Continuous drip irrigation applied to this trial to determine growth performance responses and a forced ventilated plastic covered greenhouse equipped with a "pad and fan" system was used for a closed environment system. The aim of this experiment was to determine bush tea plant growth responses to two different growing media (pine bark and sand) under a plastic covered tunnel subjected to different fertigation frequencies over time.

4.2 MATERIALS AND METHODS

4.2.1 Location

The experiment was conducted at the Hatfield Experimental Farm of the University of Pretoria, South Africa. The altitude of the Experimental Farm is 1370 m above sea level. The area is situated approximately 25^{o}45' S and 28^{o} 16' E. Frequent incidence of frost is experienced during winter months. Average annual rainfall for the year 2003 was 721.6 mm. The experiment commenced in January 2003 and ended in November 2003.

4.2.2 Collection of plant material

Bush tea plants are not commercially available and therefore, they were collected from an open field where they grew naturally in Muhuyu Village, Thohoyandou District, Limpopo Province in South Africa. Plant material with intact root were dug out from the field and transplanted into 10ℓ plastic bags to serve as stock plants. Shoots were also harvested from field plants from which rooted cuttings were made.

For the trial, about 466 cuttings were made from the collected mother plants, dipped in Seradix No.2 hormone powder (0.3 % Indole-3-Butyric Acid) and planted into a sand filled mistbed to initiate roots. The rooted cuttings were ready for transplanting after six weeks. The cuttings were hardened-off for a further 3-week period of growth in a glasshouse before these rooted plantlets were transplanted into 10ℓ black plastic bags and transferred to the tunnel in preparation for the trial. The rooted plantlets were of the same age and size when transplanted to the10ℓ black plastic bags.

4.2.3 Experimental layout and treatments

The experiment was conducted under a poly-ethylene plastic covered tunnel in which the environment (temperature and humidity) was semi-controlled with an extractor fan and a wet wall (pad and fan system). The experiment was arranged in a split-plot factorial design. The tunnel (10 x 30 m) was fitted with a drip fertigation system. Five fertigation frequencies (main plots) and two growing media (subplots), namely pine bark and sand were used in this experiment.

Forty *Athrixia* rooted plantlets were allocated per fertigation frequency, with 20 plants planted in pine bark and 20 in sand and was replicated 5 times to make a total of 200 plants. The fertigation frequencies were as follows: 2 litres/ day; 1 litre / day; 0.4 litre/ day; 2 litres every 2nd day and 2 litres/ week.

The fertilizer used was Feed-All [46], a water-soluble commercial fertilizer, containing both macro and micro-elements (Table A. 2.1, p.98). The two different growth media were chemically analyzed for nutrient status before the experiment commenced and after the experiment was completed (Tables A. 2.2 and A. 2.3, p.99). The soil properties of the two growing media were analysed at the Department of Plant Production and Soil Science at the University of Pretoria and at the Institute for Soil, Water and Climate at the Agricultural Research Council in Pretoria.

Fertilizer was applied by a computerized fertigation system at a concentration of 1 g per liter of water and as the frequency increased, the fertilizer application increased accordingly. The amount of nutrients applied through the dripper per week was analysed for each fertigation frequency (Table A. 2.4, p.100). It was calculated that fertigation frequency of 2 ℓ/day supplied 14 g of fertilizer per week, while fertigation frequency of 2 ℓ/week supplied 2 g of fertilizer per week to the plant (Table A. 2.4, p.100).

4.2.4 Data collection

Before the plants were planted into 10ℓ black plastic bags, the following parameters were taken, namely initial plant fresh mass, main stem diameter and plant height. Thereafter, non-destructive measurements of plant height, main stem diameter, fresh and dry mass of plants (includes roots, flowers, stems and shoots, leaves), number of stems (main shoot from roots) and number of shoots (twigs on stems) were taken at 90, 180 and 270 days after planting (DAP). Flower measurements were also taken depending on the flowering season, which included counting the number of flowers, and then weighing their fresh and dry mass. Flowers were also categorized into three parts, as open, closed and dead. After the second harvest plants were cut back in order to generates new shoots

At three-month intervals, six plants were destructively harvested randomly from each of the five fertigation frequencies. In total, thirty plants were harvested at three month intervals in May (90 DAP), August (180 DAP) and November (270 DAP), which represented a winter, spring and summer harvest season. Minimum and maximum daily temperatures were recorded from the start until the end of the experiment. Temperature in the tunnel ranged between 5^{o}C (minimum) and 30^{o}C (maximum) (Figure A. 2.1. p.98).

During harvesting, plants were uprooted from their growing media and the roots were cleaned. The following destructive measurements were then taken after harvest namely: fresh and dry mass of leaves, roots, stems with shoots; stem diameter area and maximum root length. For dry mass measurements, the fresh leaves, roots as well as stems with shoots were placed in clean brown paper bags and dried in an oven at a temperature of 65^{o}C for three days. Water content and percentage dry matter were calculated as follows:

Water content (%) = [(FM-DM)/FM] x 100

Percentage dry mass (%) = (DM / FM) x 100; where FM = fresh mass and DM = dry mass

4.2.5 Statistical analysis

Data were analyzed in the Department of Statistics using the General Linear Model (GLM) procedure in the Statistical Analysis System (SAS) statistical package. The data collected were subjected to ANOVA (Statistical Analysis System Institute Inc., Cary, NC, USA, Copyright © 1999-2000). Standard errors were calculated and SAS means procedure (GLM procedure) at 5% level of confidence was used to interpret the results (See Appendix 3 (p. 101-104).

4.3 RESULTS

4.3.1 Growth performance

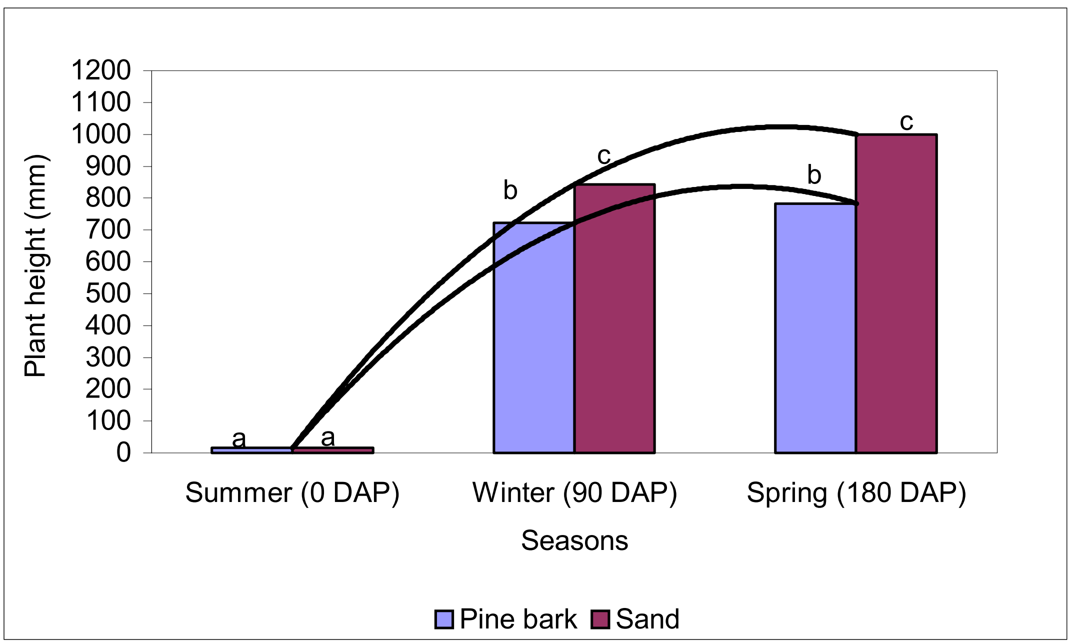
Data collected during the winter and spring season harvests showed that growth medium had significant results on growth and yield of bush tea. Fertigation frequency also influenced plant growth throughout the entire experiment. However, the interaction between growing medium and fertigation frequency had no significant effect on the growth performance of bush tea except for dry root mass at 180 days after planting. After the second harvest (winter grown plants), the plants were cut back in the tunnel to generate new shoots. It was done as practiced in Venda after flowering, by means of cutting the plants at the base of the stems. Similar pruning practices are conducted on roses, for example. Surprisingly, few of the plants survived the cutting back, which resulted in having insufficient data plants for the last harvest in November. The results for the summer harvest could therefore not be included in this dissertation.

4.3.2 Growing medium and fertigation frequency effects

A good hydroponics medium should support the plants in the system, not break down, absorb and retain moisture, be porous to allow air circulation and have proper drainage, and be able to protect plant roots from extreme temperatures (Niederwieser, 2001). The analysis report from two different growing media showed that both growing media under the higher fertigation frequencies leached more and retained nutrients than those from the lower fertigation frequency (Table A. 2.2 and A. 2.3, p.99).

4.3.2.1 Plant height

There were no interactions between fertigation frequency and growing medium for plant height of bush tea at 90 and 180 days after planting (DAP). Growth medium had a significant effect on plant height of bush tea throughout the whole experiment. At 90 DAP, plants were taller in the sand media as compared to plants grown in pine bark. Similar results were found during the spring (180 DAP) harvest (Fig. 4.1). The curve lines in Fig. 4.1 showed that, from days after planting (summer), the growth was fast, but slowed down after the winter harvest.

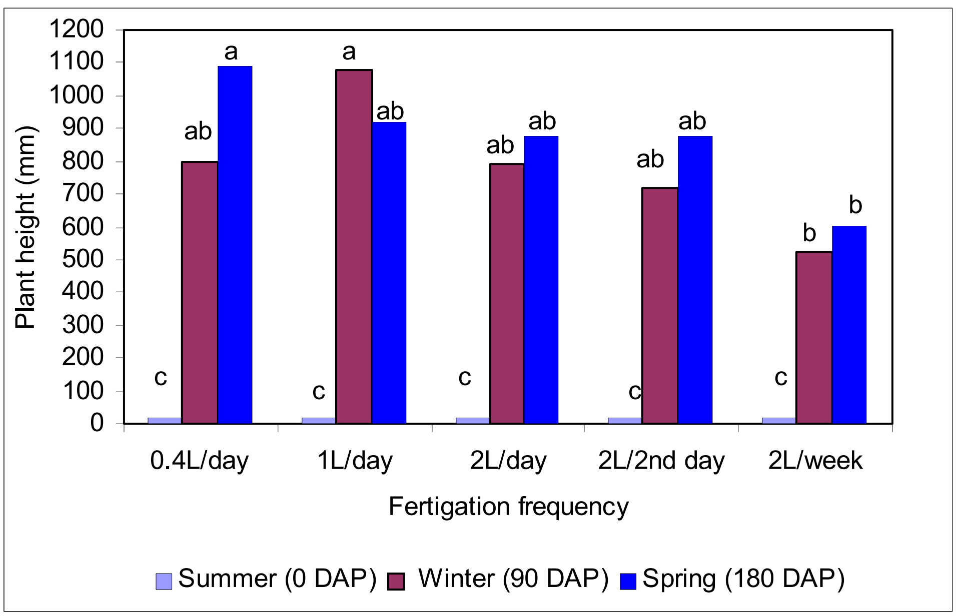


Treatment means with letters in common are not significantly different at P≤0.05

Figure 4.1 Plant height as affected by growth medium at 90 and 180 days after planting (DAP)

Fertigation frequency affected plant growth during the 8-month growing cycle (180 days). Plants grew dramatically from an initial height of 157mm to a height of about

1080mm at 90 DAP. During this time, plants that received a high fertigation frequency of 1 ℓ/day resulted in taller plants (1080 mm) as compared to plants that received a low fertigation frequency of 2 ℓ/week (600 mm tall) (Fig. 4.2) at 90 DAP. Plants that were fertigated with 0.4 ℓ/day also resulted in taller plants compared to plants fertigated with 2 ℓ/week at 180 DAP. At 90 days after planting, there were no significant differences ($P \leq 0.05$) in plant height between the plants that received fertigation of 0.4 ℓ/day, 2 ℓ/day, 2 ℓ/2nd day and 2 ℓ /week. At 180 DAP after winter growth, there was also no significant difference in plant height of plants that received 1 ℓ/day, 2 ℓ/day, 2 ℓ/2nd and 2 ℓ /week (Fig. 4.2). In general, plants did not grow much during the winter period, because they were preparing for a dormant period after flowering.



Treatment means with letters in common are not significantly different at P≤0.05

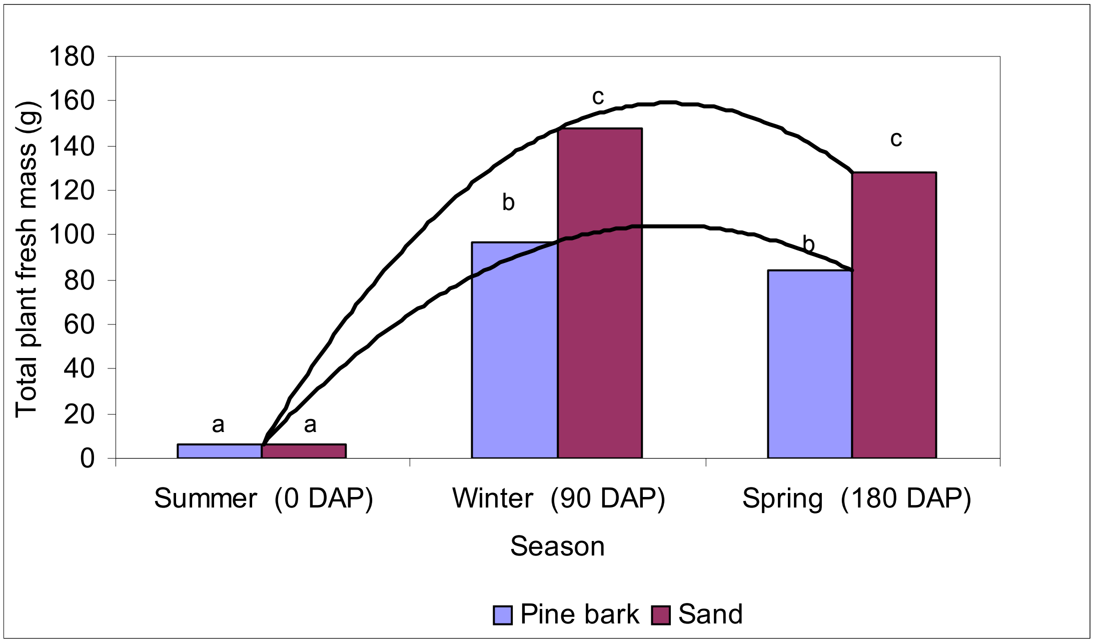
Figure 4.2 Plant heights as affected by fertigation frequency at 90 and 180 days after planting (DAP)

4.3.2.2 Total plant fresh and dry mass

There were no interactions between growing medium and fertigation frequency for total plant fresh mass (Table A. 3.2-3, p.101-102) at 90 DAP and 180 DAP. However, the fresh mass was significantly affected by growing medium at 90 and 180 DAP (Fig. 4.3). Plants grown in sand produced a significantly greater total fresh mass compared to those of pine bark plants in both seasons at 90 and 180 DAP. From summer to winter the fresh mass increased almost linearly. However, after winter the plants grew at a slow rate thus resulting in decreased fresh mass in spring. During spring harvest brown (almost dead) leaves were seen with lower water content and which may explain the decreases in plant fresh mass.

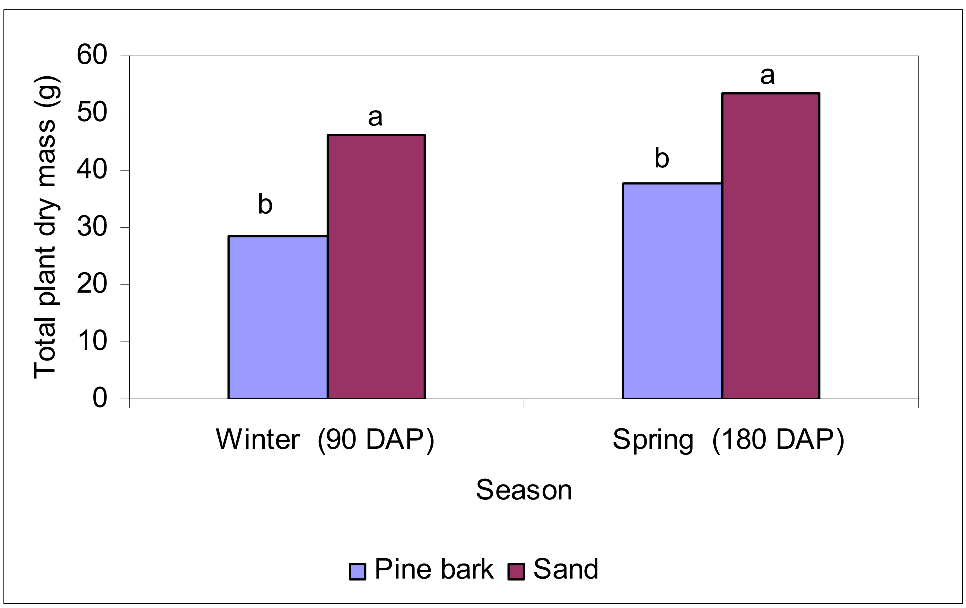
Similar to the influence on fresh mass, growing medium had a marked effect on the total dry mass of bush tea (Fig. 4.3). When comparing pine bark and sand media on dry mass basis, plants that were grown in sand had higher dry mass at 90 and 180 DAP. Although there was a decrease in fresh mass of bush tea from the winter harvest compared to the spring harvest, there was no decrease in dry mass from winter to spring harvest (Fig. 4.3 and Fig.4.4).

Figure 4.5 illustrates that plants that received 1 ℓ/day had significantly greater fresh mass compared to plants that received 2 ℓ/week at 90 DAP. At 180 DAP, a similar trend was observed in terms of total fresh mass amongst the fertigation frequencies. Similar results were found when the total dry mass was measured (Fig. 4.6). Plants fertigated with 1 ℓ/day resulted in a greater total dry mass compared to other fertigation frequencies and showed a similar trend at 180 DAP. Therefore, a fertigation frequency of 1 ℓ/day was found to be an optimal fertigation frequency for maximum total fresh and dry mass of the plant regardless of sampling date.



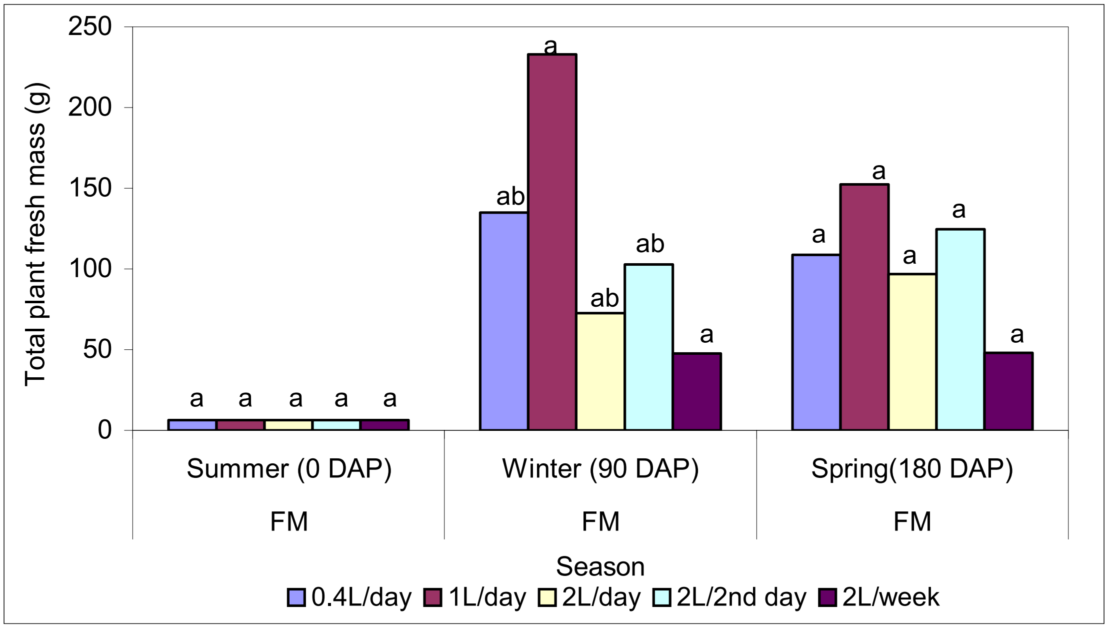
Treatment means with letters in common are not significantly different at P≤0.05

Figure 4.3 Total fresh mass of bush tea as influenced by growth media at 90 and 180 days after planting (DAP)



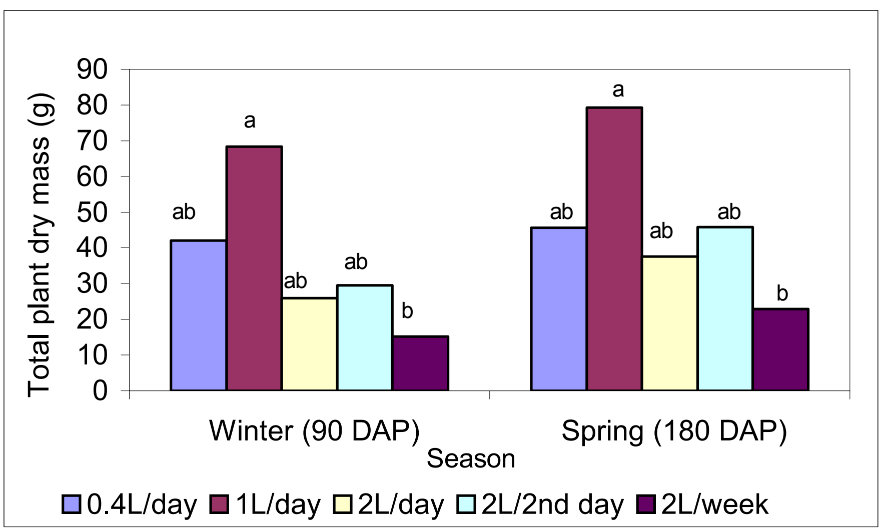
Treatment means with letters in common are not significantly different at P≤0.05

Figure 4.4 Total dry mass of bush tea as influenced by growth media at 90 and 180 days after planting (DAP)



Treatment means with letters in common are not significantly different at P≤0.05

Figure 4.5 Total fresh mass of bush tea as influenced by fertigation frequency at 90 and 180 days after planting (DAP)

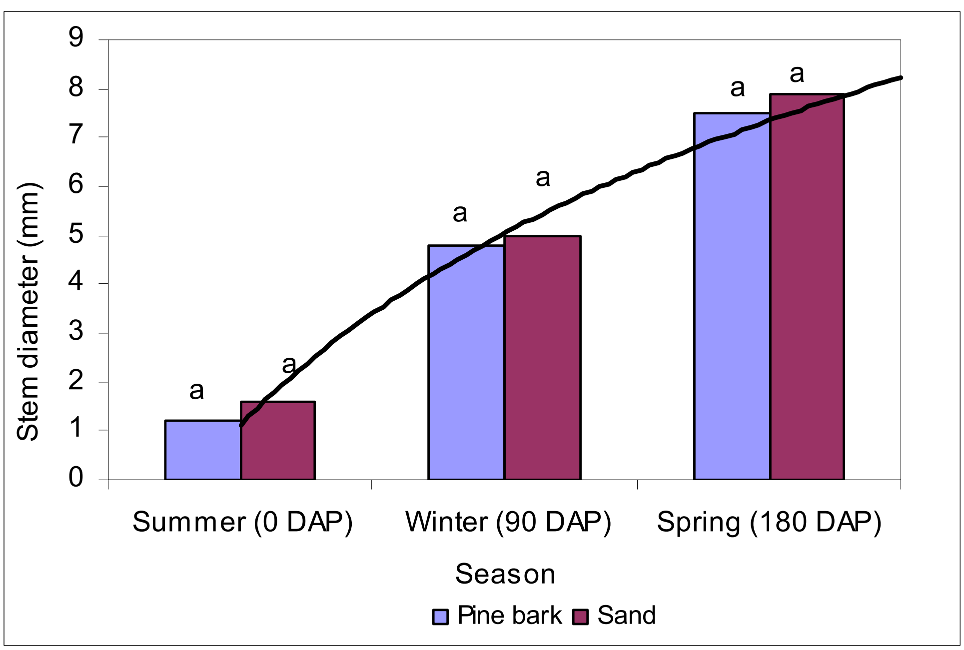


Treatment means with letters in common are not significantly different at P≤0.05

Figure 4.6 Total dry mass of bush tea as affected by fertigation frequency at 90 and 180 days after planting (DAP)

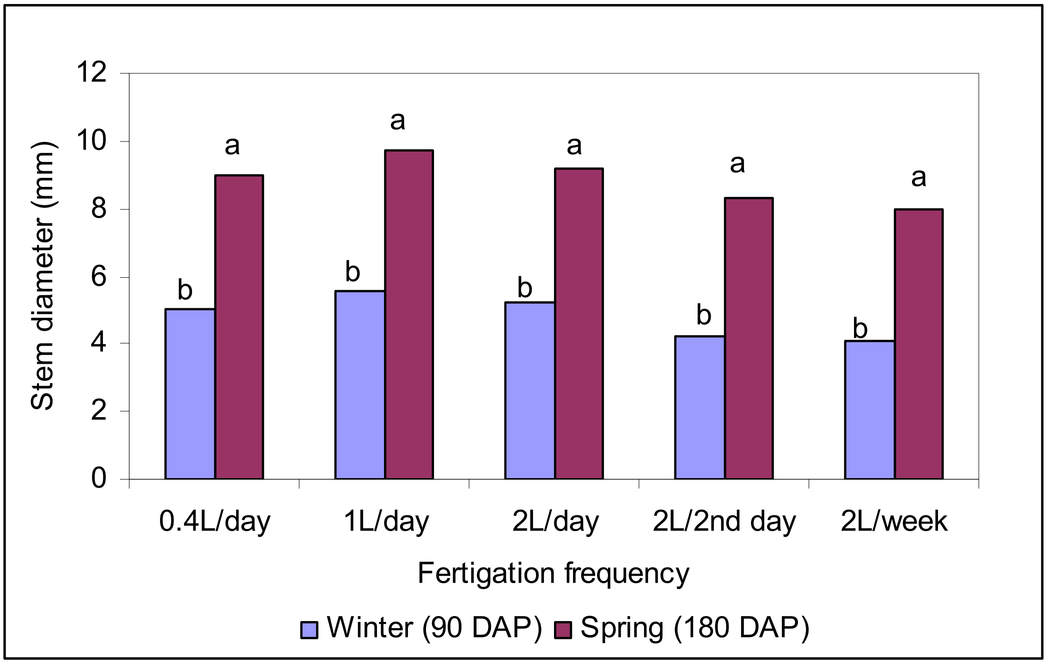
4.3.2.3 Stem diameter

Stem diameter of bush tea was not significantly affected by the different growing media (Fig. 4.7) (Tables A. 3.1 and 3.7, pp. 101 and 104). In addition, there were no interactions between growing medium and fertigation frequency for stem diameter. However, in terms of stem development, at 90 days after planting, plants showed thicker stems when grown in sand compared to pine bark grown plants. Similar tendency was observed at 180 days after planting, illustrating that sand grown plants had thicker stems than pine bark grown plants (Fig. 4.7). This could be due to a lower number of stems, thus energy available was allocated to the stem thickness. Although the results for stem diameter were not significantly different, it was interesting to note that the fertigation frequency of 1 ℓ/day resulted in plants with non-significantly thicker stems (about 10mm) than the rest of the fertigation frequencies (Fig. 4.8). Stem diameter almost doubled in size from 90 DAP to 180 DAP, which showed a good growth performance.



Treatment means with letters in common are not significantly different at P≤0.05

Figure 4.7 Stem diameters as affected by growing media from summer to spring season. DAP = days after planting



Treatment means with letters in common are not significantly different at P≤0.05

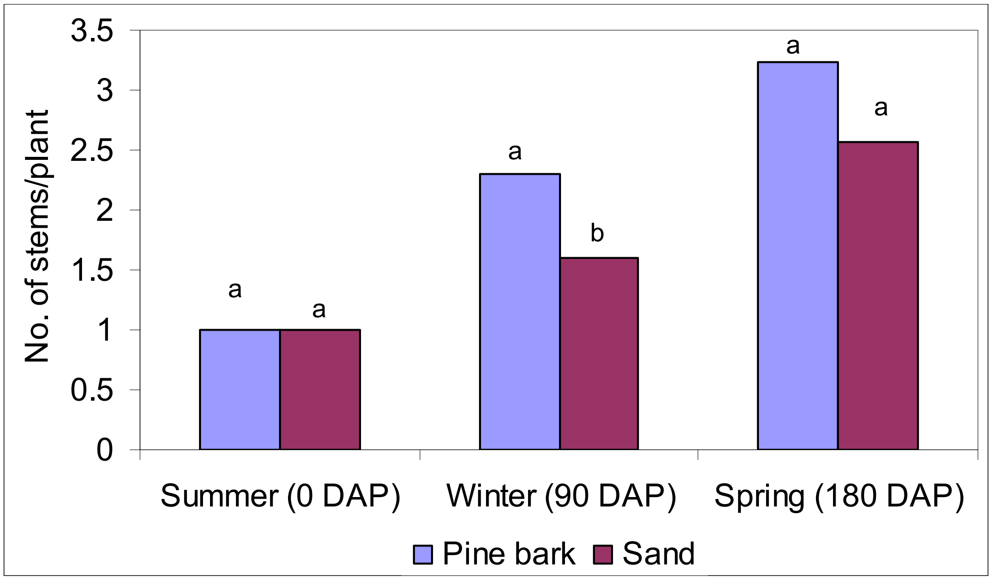
Figure 4.8 Stem diameters as affected by fertigation frequency at 90 and 180 DAP. DAP= days after planting

4.3.2.4 Number of stems

There were no interactions between growth medium and fertigation frequency for number of stems (Table A. 3.1, p. 101). There was low production of stems during the vegetative growth in autumn season, while the number of stems had increased in the spring harvest (Fig. 4.9). Plants that were grown in pine bark produced more stems as compared to sand grown plants in at 90 DAP. When harvesting in spring (180 DAP), however, growing medium did not have a significant influence on number of stems (Fig. 4.9).

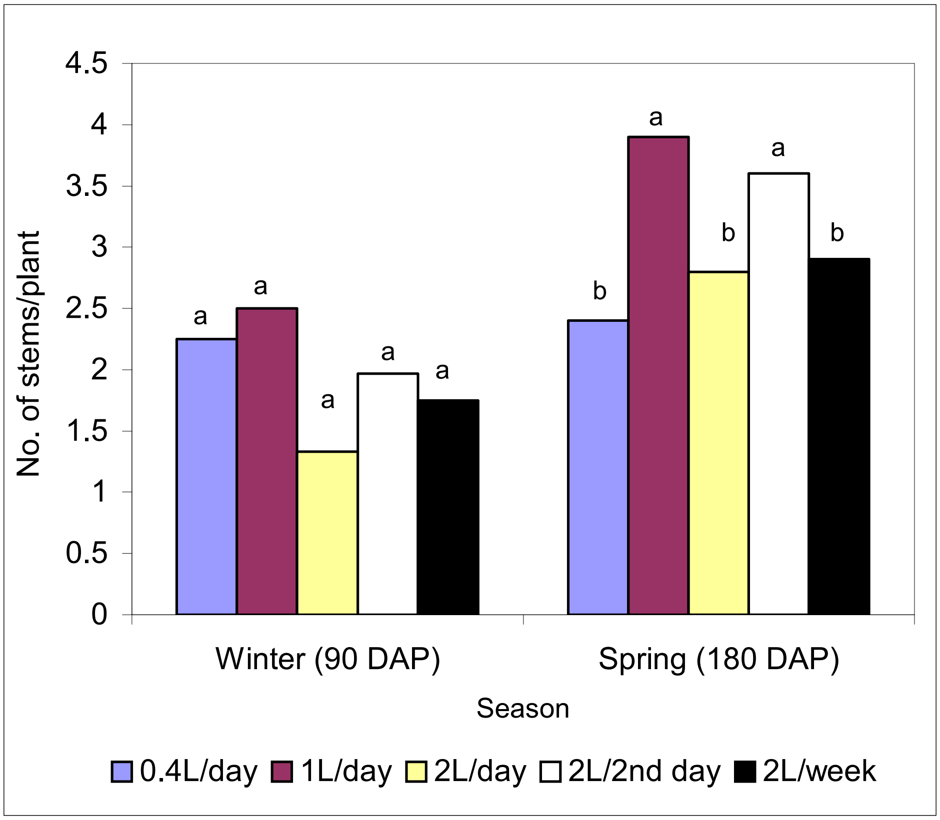
There were no significant differences in stem production due to fertigation frequency at 90 DAP (Fig. 4.10). However, plants fertigated with 1 ℓ/day and 2 ℓ/2nd produced significantly more stems at 180 DAP (spring) compared to plants that received 0.4 ℓ/day, 2 ℓ/day and 2 ℓ/week. No significant differences were found with other frequencies at 180

DAP on stem production. Fertigation frequencies of 1 ℓ/day and 2 ℓ/2nd were, therefore, ideal for branching, as they produced more stems than any other fertigation frequency (Fig. 4.10).



Treatment means with letters in common are not significantly different at P≤0.05

Figure 4.9 Number of stems as affected by growing medium at 90 DAP and 180 DAP. DAP = days after planting



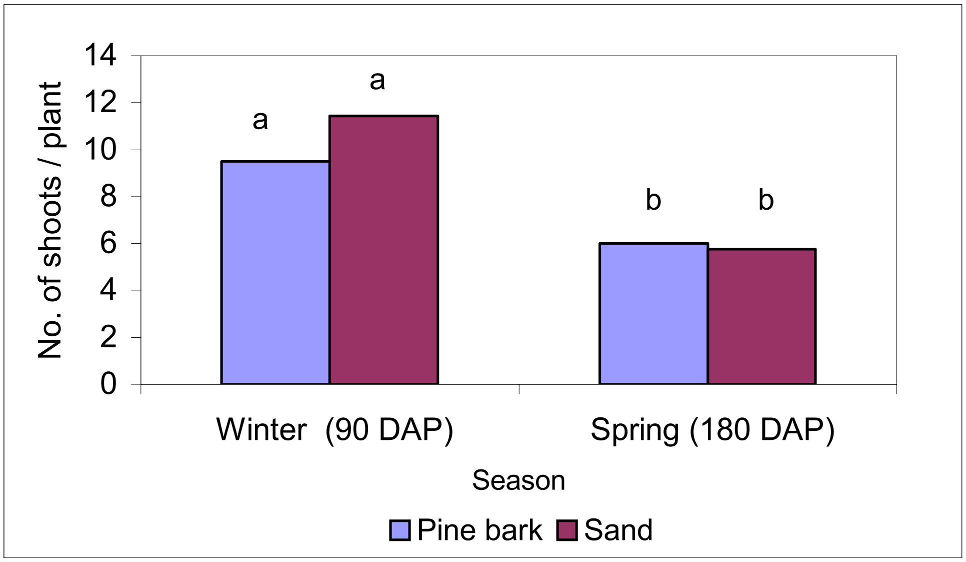
Treatment means with letters in common are not significantly different at P≤0.05

Figure 4.10 Number of stems as affected by fertigation frequency at 90 and 180 days after planting (DAP)

4.3.2.5 Number of shoots

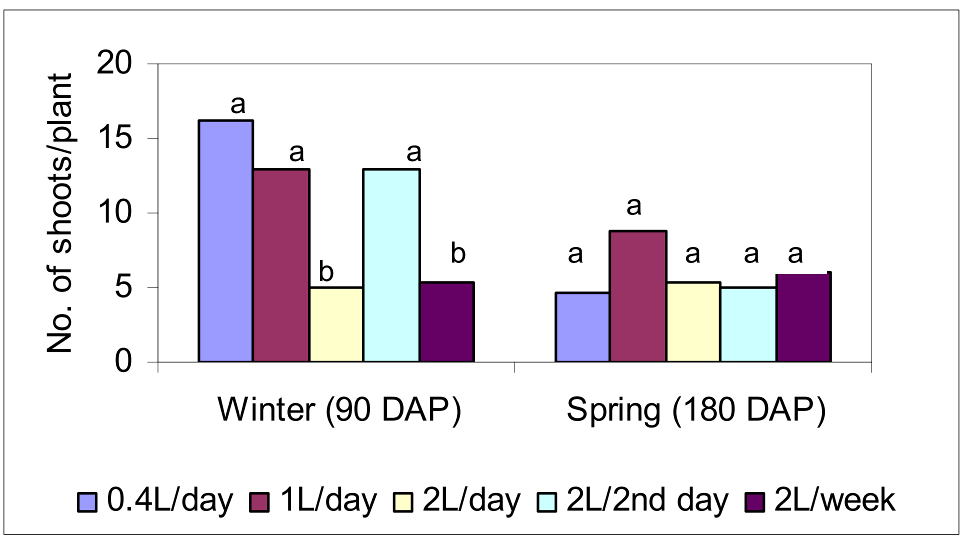
The results showed no interactions between fertigation frequency and growing medium for member of shoots (Table A 3.1, p. 100). At both harvesting dates, the two growing media showed no significant difference in the number of shoots per plant (Fig. 4.11). However, the number of shoots decreased drastically during the winter growth, which is illustrated by the spring harvest results.

At 90 DAP, plants fertigated with 2 ℓ/day and 2 ℓ/week, resulted in a lower number of shoots as compared to plants that received 0.4 ℓ/day, 1 ℓ/day and 2 ℓ /2nd day. However, the number of shoots were the same for all treatments at 180 DAP (Fig. 4.12). The results indicated that fertigation frequency of 1 ℓ/day was promising for continuous healthy shoot growth (Fig. 4.12).



Treatment means with letters in common are not significantly different at P≤0.05

Figure 4.11 Number of shoots as affected by growing medium at 90 and 180 days after planting (DAP)

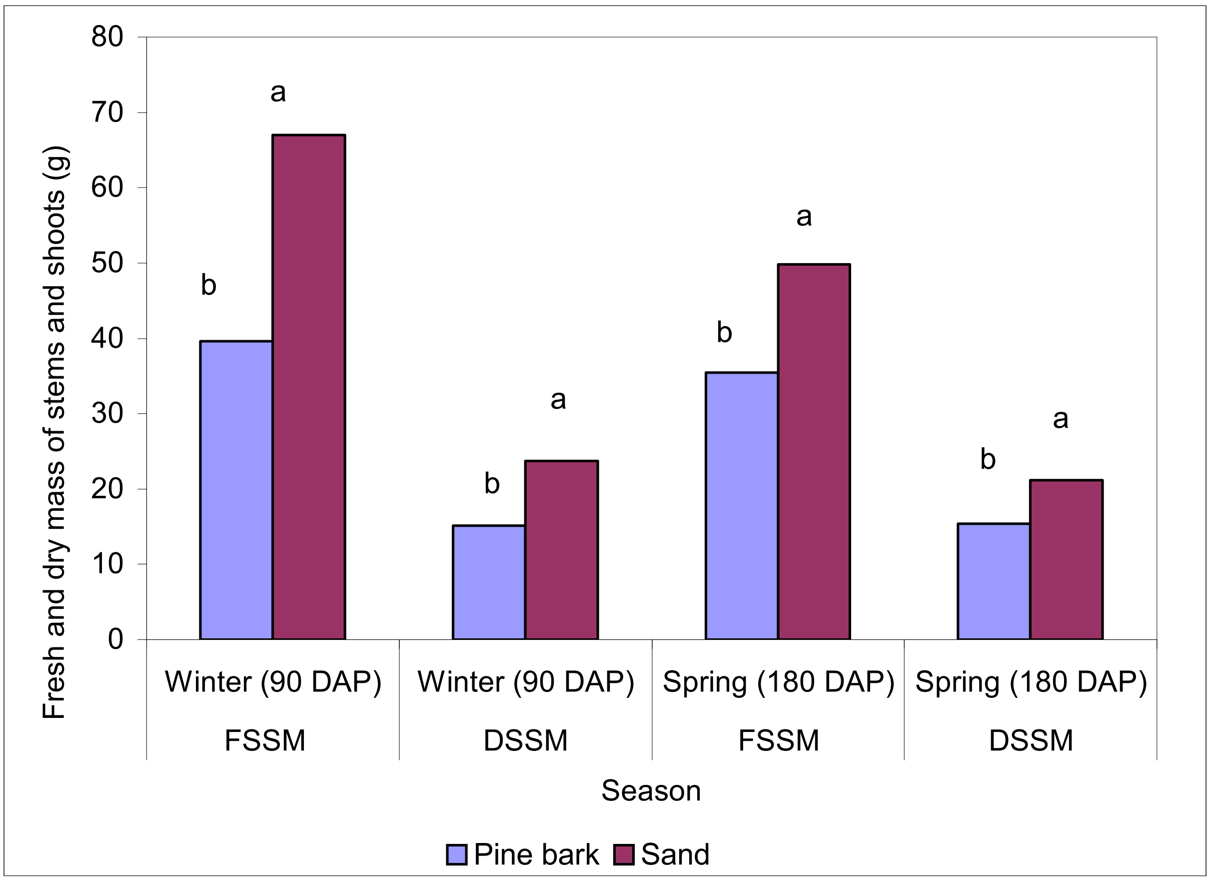


Treatment means with letters in common are not significantly different at P≤0.05

Figure 4.12 Number of shoots as affected by fertigation frequency at 90 DAP and 180 DAP. DAP = days after planting

4.3.2.6 Total fresh and dry mass of stems and shoots

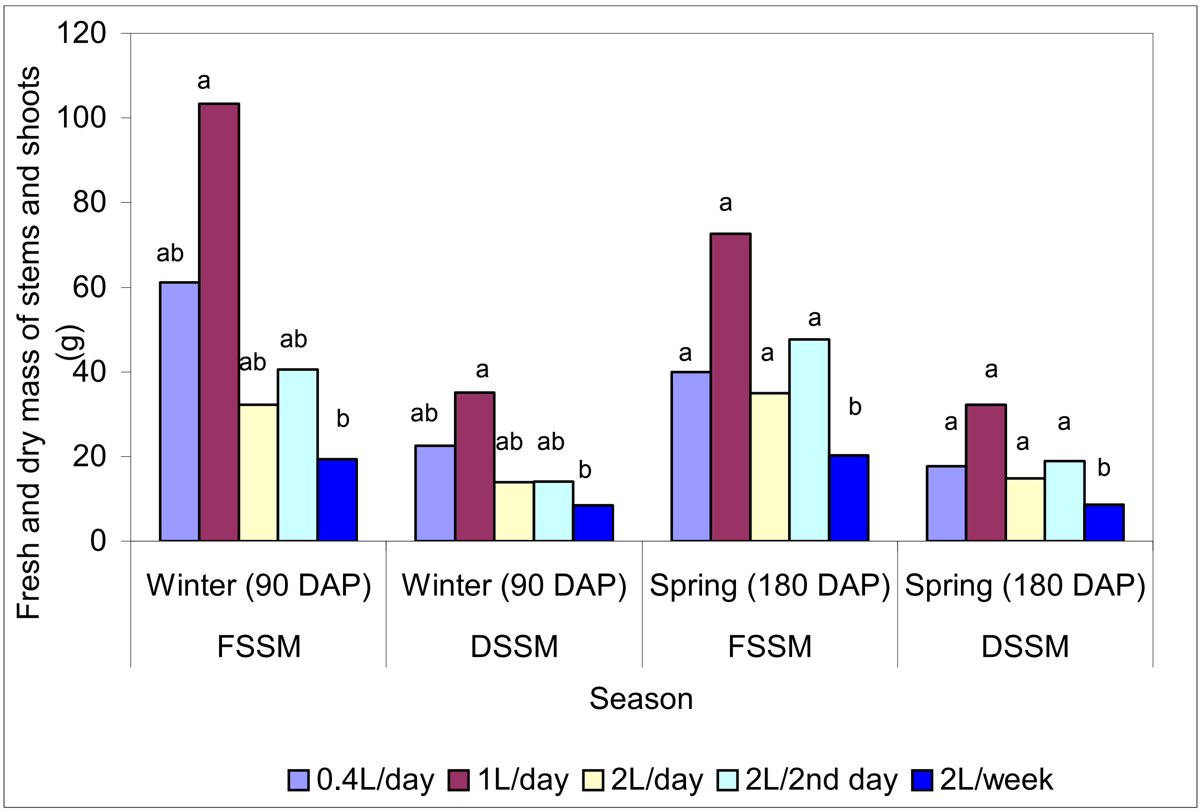
There were no interactions between the growing medium and fertigation frequency in terms of fresh and dry stem and shoot mass (Tables A. 3.1-6, p. 101-103). Fresh stem and shoot mass was greater during the first harvesting period (90 DAP) compared to the second harvesting period (180 DAP) (Fig. 4.13). In both seasons (winter and spring) the fresh and dry mass of the stems and shoots were higher in sand grown plants as compared to those of the pine bark grown plants.



Treatment means with letters in common are not significantly different at P≤0.05

Figure 4.13 Fresh and dry mass of stems and shoots of bush tea as influenced by growing medium at 90 and 180 days after planting (DAP); FSSM = fresh stem and shoot mass; DSSM = dry stem and shoot mass

Plants that received 1 ℓ/day fertigation had higher fresh and dry mass of stems and shoots compared to those of plants that received 2 ℓ/week at 90 DAP and 180 DAP (Fig. 4.14). At 90 DAP (winter), plants that received fertigation a frequency of 2 ℓ/day, 2 ℓ/2nd day and 0.4 ℓ/day resulted in close to half the fresh mass in stems and shoots compared to the plants fertigated with 1 ℓ/day. The fertigation frequency 2 ℓ/week thus resulted in retarded growth.



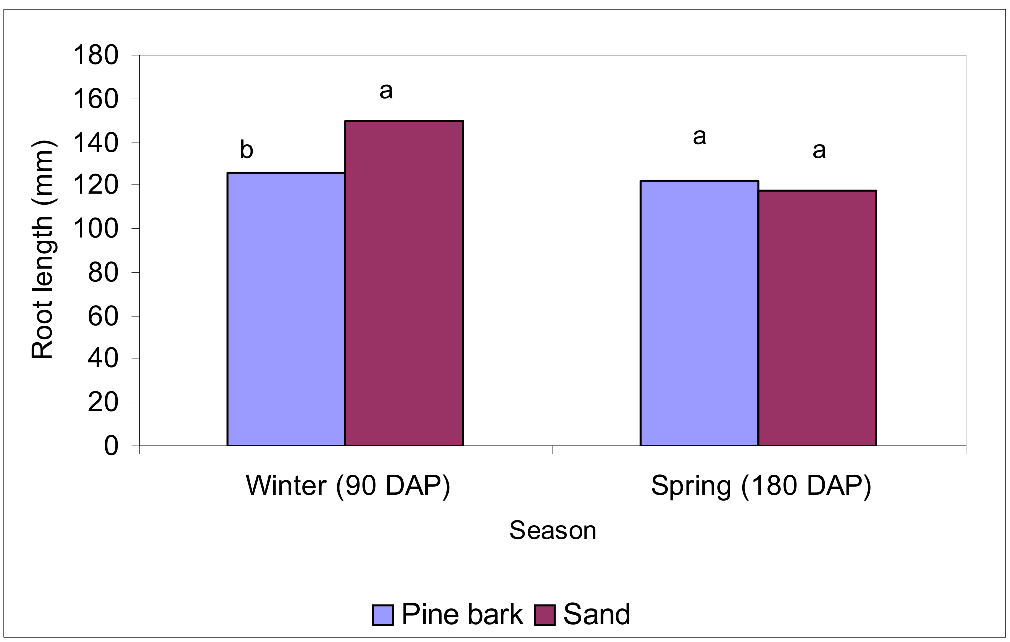
Treatment means with letters in common are not significantly different at P≤0.05

Figure 4.14 Fresh and dry mass of stems and shoots of bush tea as influenced by fertigation frequency at 90 DAP and 180 DAP. DAP = days after planting; FSSM = fresh stem and shoot mass; DSSM = dry stem and shoot mass

4.3.2.7 Root length

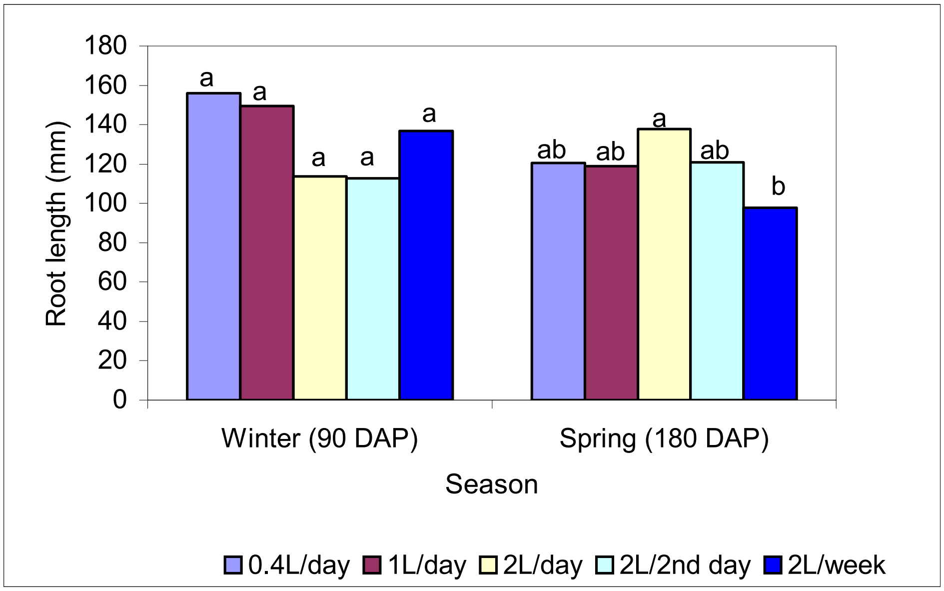
There were no interactions between fertigation frequency and growing media for root length (Tables A. 3.1 and A. 3.7, p. 101 and 103). At 90 days after planting, sand grown plants had significantly longer roots than pine bark grown plants (Fig. 4.15). However, at 180 days after planting, there was no difference in root. Generally, the results showed a decrease in root length of bush tea plant from 90 DAP to 180 DAP (Fig. 4.15).

At 90 DAP, there were no significant differences (P≤0.05) in root length of bush tea when treated with five fertigation frequencies. However, at 90 DAP, plants that received higher fertigation frequency of 2 ℓ/day produced longer roots (137.9 mm) as compared to plants that received 2 ℓ/ week fertigation (Fig. 4.16). The results were not significantly different for plants that received fertigation frequencies of 1 ℓ/day, 0.4 ℓ/day and 2 ℓ/2nd day, but the root length tended to be higher than those of plants fertigated with 2 ℓ/week. This illustrated that root growth (length) is enhanced by an increase in water availability.



Treatment means with letters in common are not significantly different at P≤0.05

Figure 4.15 Root length as affected by growing medium at 90 and 180 days after planting (DAP)

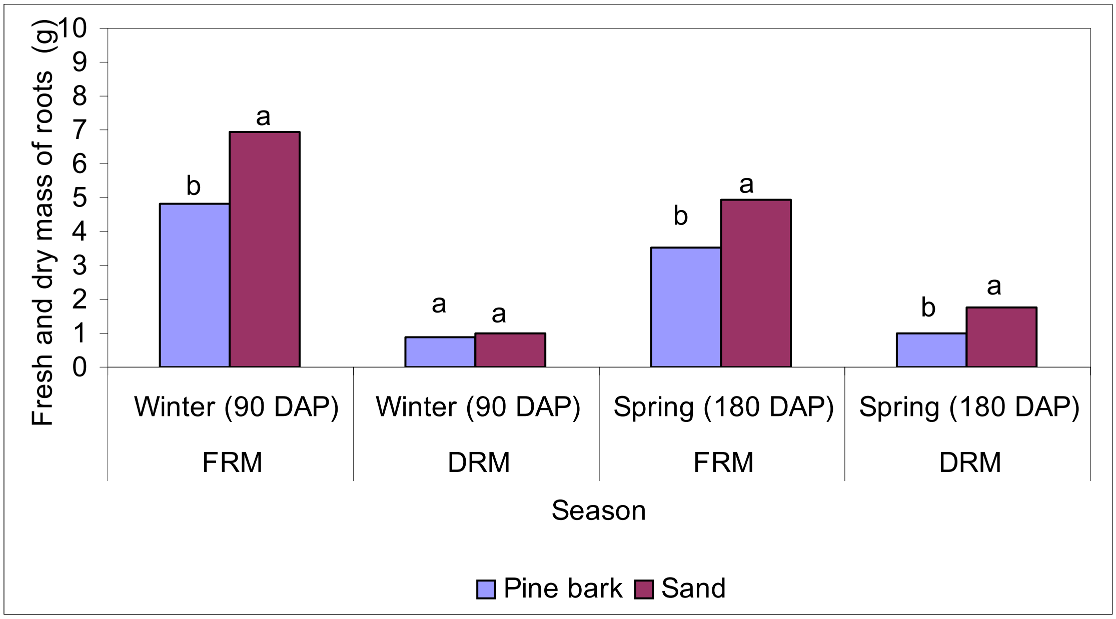


Treatment means with letters in common are not significantly different at P≤0.05

Figure 4.16 Root length as affected by fertigation frequency at 90 and 180 days after planting (DAP)

4.3.2.8 Fresh and dry mass of roots

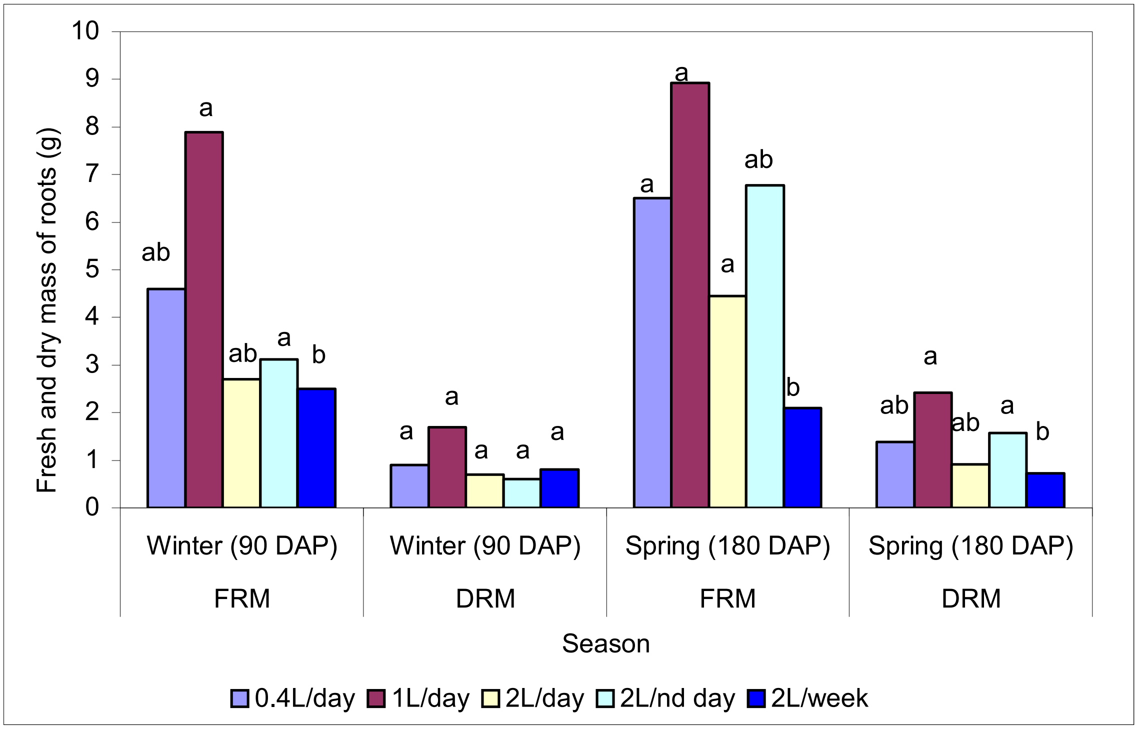
There were significant differences in fresh root mass for plants grown in different growing media (Table A. 3.3, p.102). There were also interactions between growing media and fertigation frequencies in terms of dry root mass (Table A. 3.6, p.103). The fresh root mass was higher during the first harvesting period (90 DAP) compared to the second harvesting period (180 DAP) (Fig. 4.17). At 90 and 180 DAP fresh mass of roots was higher in sand grown plants compared to those of the pine bark grown plants (Fig. 4. 17). Sand growing media thus produced plants with a higher root mass.



Treatment means with letters in common are not significantly different at P≤0.05

Figure 4.17 Fresh and dry mass of roots of bush tea as influenced by growing medium at 90 and 180 days after planting (DAP); FRM = fresh root mass; DRM = dry root mass

It was found that fertigation frequency affected the root mass of bush tea in both seasons (Fig. 4.18). At 90 days after planting, plants that received a fertigation frequency of 1 ℓ/day resulted in plants with the highest fresh root mass and the lowest fertigation frequency resulted in plants with the lowest dry and fresh root mass. Plants that received the highest (2 ℓ/day) and lowest (2 ℓ/week) amount of water had an overall negative effect on root growth, since root mass obtained was lower than expected (Fig. 4.18). Therefore, these results indicate that the amount of fertilizer and irrigation does have an effect on root growth.



Treatment means with letters in common are not significantly different at P≤0.05

Figure 4.18 Fresh and dry mass of roots of bush tea as influenced by fertigation frequency at 90 and 180 days after planting (DAP); FRM = fresh root mass; DRM = dry root mass

The interactions between growing media and fertigation frequency significantly affected dry root mass of bush tea at 180 DAP (Table 4.1). Sand grown plants that were fertigated with 1 ℓ/day and 2 ℓ/2nd day had a significantly higher dry root mass at 180 DAP compared to those in pine bark. On the other hand, plants grown in pine bark had a significantly higher root dry mass when fertigated with 0.4 ℓ/day compared to those from the sand. Dry root mass was drastically lower when plants received 2 ℓ/day, 2 ℓ /2nd day and 2 ℓ /week, when grown in both growing media (pine bark and sand). There appears to be an optimum fertigation frequency requirement rather than a lower or higher fertigation frequency requirement for both growing media.

Table 4.1 Interactive effects of fertigation frequency and growing media on the dry root mass of bush tea at 180 days after planting (spring harvest)

Fertigation frequency	Growing media	Root dry mass (g)
0.4 ℓ/day	Pine bark	1.71[abc]
	Sand	1.16[bc]
1 ℓ/day	Pine bark	1.16[bc]
	Sand	3.89[a]
2 ℓ/day	Pine bark	0.93[d]
	Sand	0.88[d]
2 ℓ/2[nd] day	Pine bark	0.77[de]
	Sand	2.79[ab]
2 ℓ /week	Pine bark	0.43[def]
	Sand	0.95[d]

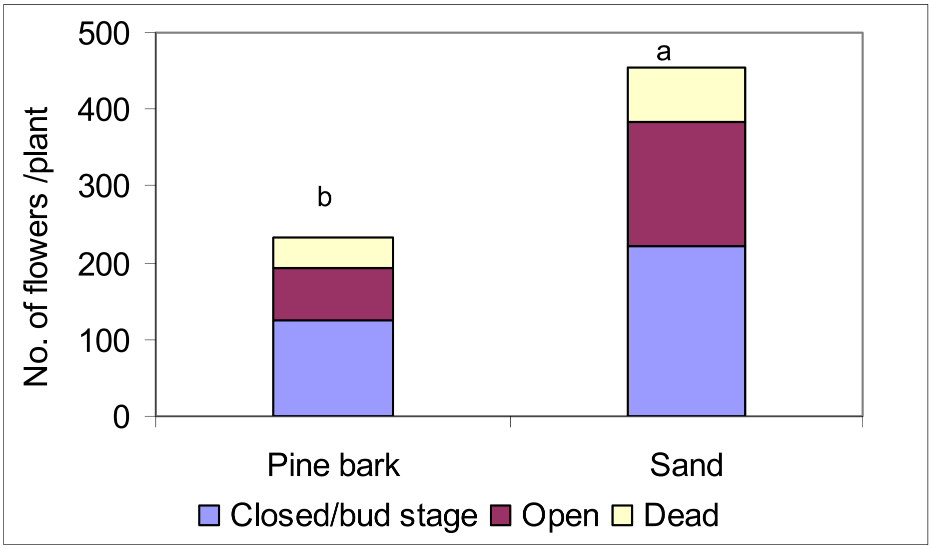
Values with the same letter are not significantly different at P≤0.05

4.3.2.9 Number of flowers

There were no interactions between growing media and fertigation frequency in terms of number of flowers as well as fresh and dry mass of flowers of bush tea (Table A. 3.7, p.104). Figure 4.19 shows a bush tea plant in flower. However, the two growing media affected the number of flowers according to spring harvest results. Plants grown in sand media had more flowers as compared to those of pine bark grown plants (Fig. 4.20). It was also observed that flowers were first initially noted on sand grown plants during early May. The flowers from sand grown plants increased to more than double their number (360/plant) as compared to the flowers harvested from the pine bark grown plants (Fig. 4. 20). A possible explanation is that more nutrients were available in the growing media or this can also be because of the built up of salt in the sand media, the plant was under stress thus tended to flower earlier (see Table A 2.2. and A 2.3, for micro and macro status of the growing media).

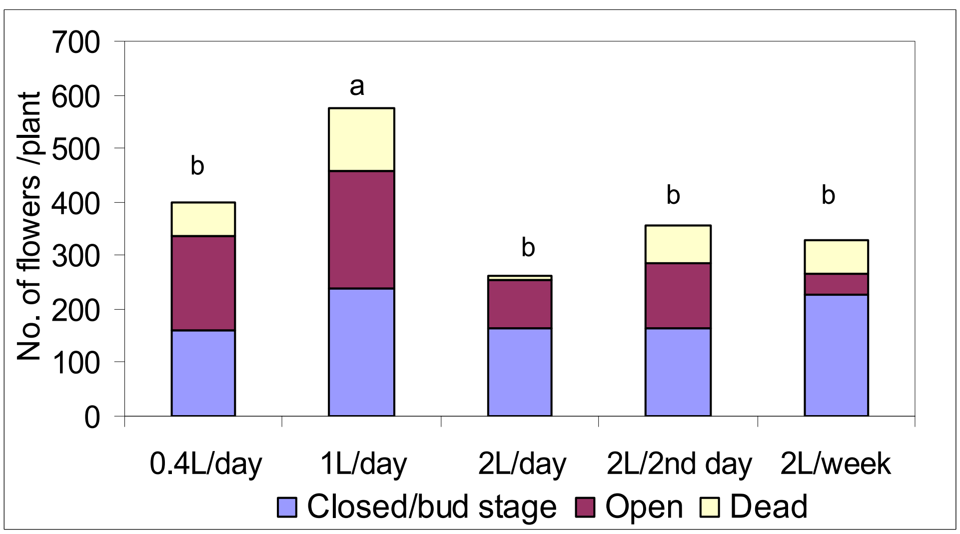
Figure 4.19 Bush teas at flowering stage in a plastic tunnel at 180 days after planting

Plants that received 1 ℓ/day significantly produced higher number of flowers compared to plants fertigated with 0.4 ℓ /day, 2 ℓ/day, 2 ℓ/2nd and 2 ℓ/week day at 180 days after planting (Fig. 4.21). Fertigation application of 2 ℓ/day (highest) had a negative effect on flower production, as this frequency resulted in the lowest number of flowers per plant. It was, therefore, concluded that an application of 1 ℓ/day was an ideal frequency for flower production of bush tea.



Treatment means with letters in common are not significantly different at P≤0.05

Figure 4.20 Number of bush tea flowers as affected by growing media when harvested in spring



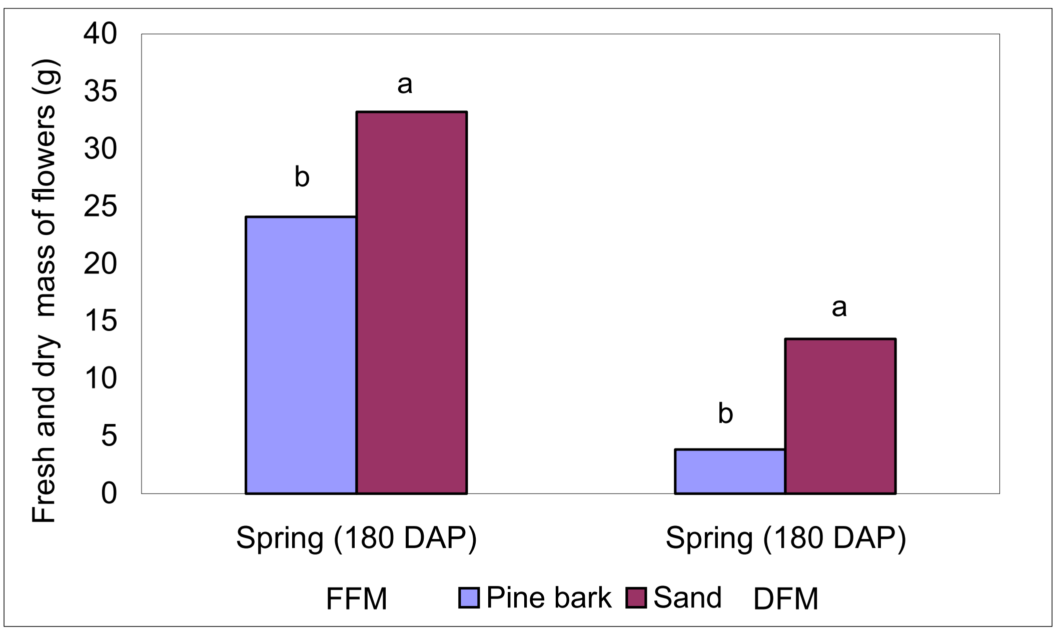
Treatment means with letters in common are not significantly different at P≤0.05

Figure 4.21 Number of bush tea flowers as affected by fertigation frequency when harvested in spring

4.3.2.10 Fresh and dry mass of flowers

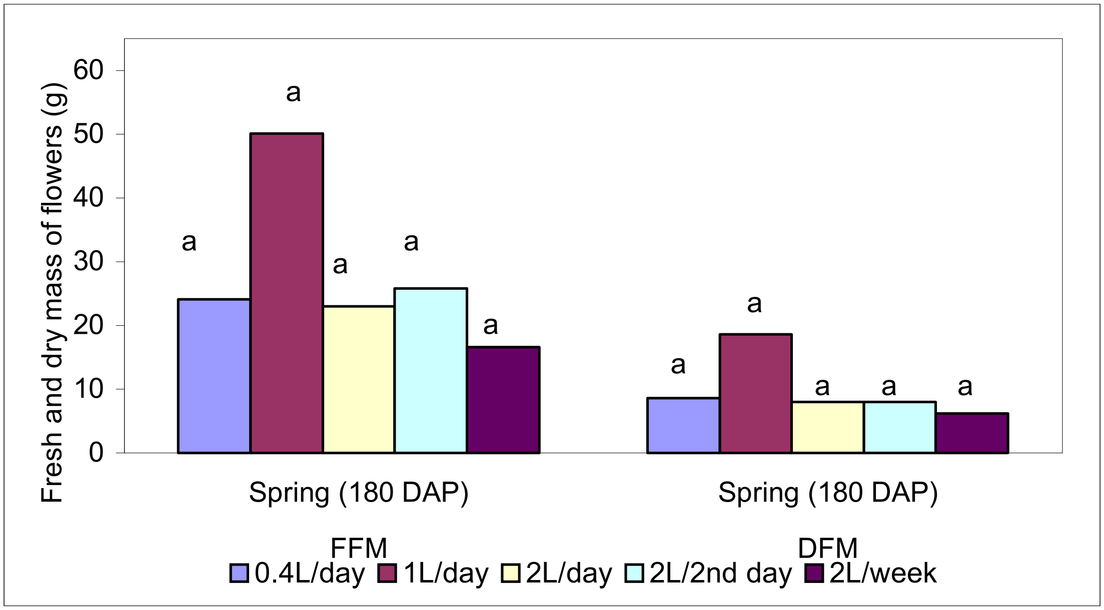
There were no interactions between growing media and fertigation frequency in terms of fresh and dry flower mass of bush tea at 180 DAP (Table A. 3.7, p.104). Due to the fact that flowers were only visible during winter season, only results from the spring harvest will be discussed (Fig. 4.22). The two growing media had a significant effect on flower fresh and dry mass (Table A. 3.7, p.104). Both fresh and dry masses of flowers were higher of sand grown plants compared to pine bark grown plants. Flower production of sand grown plant was thus higher.

Fertigation frequency did not affect flower fresh and dry mass of bush tea (Table A. 3.7, p.104). However, at 180 days after planting, plants that received a fertigation frequency of 1 ℓ/day had non significantly higher flower fresh mass compared to the other fertigation frequencies.



Treatment means with letters in common are not significantly different at P≤0.05

Figure 4.22 Fresh and dry mass of flowers as influenced by growing medium at 180 days after planting (DAP); FFM = fresh flower mass; DFM = dry flower mass



Treatment means with letters in common are not significantly different at P≤0.05

Figure 4.23 Fresh and dry mass of flowers as influenced by fertigation frequency at 180 days after planting (DAP); FFM = fresh flower mass; DFM = dry flower mass

4.3.2.11 Fresh and dry mass of leaves

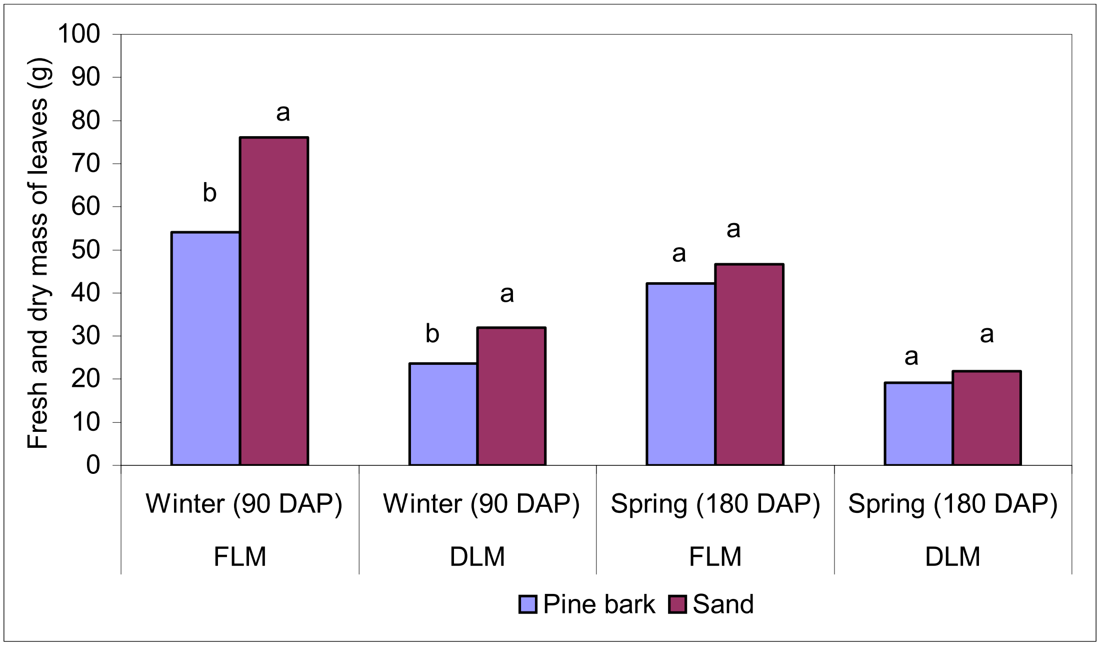
There were no interactions between the growing media and fertigation frequency on leaf fresh and dry mass of bush tea (Table A. 3.1-6, pp.103-107) at 90 DAP and 180 DAP. During the autumn season the moisture content in the leaves (when harvested in winter), was higher compared to the moisture content of the leaves from winter season when harvested during spring (Table 4.2). The water content of leaves of the plants grown in the two different growing media under five fertigation frequencies were above 60% during both seasons (Table 4.2). In addition, there were no significant differences between the two growing media in terms of water content of the leaves of bush tea.

The fresh leaf mass was significantly higher at the first harvesting period (90 DAP) compared to the second harvesting period (180 DAP) (Fig. 4.24). At the winter harvest, the fresh and dry mass of leaves was higher in sand compared to those of the pine bark grown plants. At the spring harvest, no significant results were measured for the fresh and dry mass of leaves. This shows that leaf growth was faster for sand grown plants from summer to winter. In overall, there was not much increase in leaf dry mass from winter harvested plants compared to spring harvested plants.

Table 4.2 Influence of growing media and fertigation frequency on the water content and dry mass percentage of leaves of *Athrixia phylicoides*

	Leaves	
	Water content (%)	**Dry mass (%)**
Bark	66.08 [a]	33.91 [a]
Sand	64.86[a]	35.14 [a]
90 DAP Winter Harvest	72.74 [a]	27.26 [b]
180 DAP Spring Harvest	53.70[b]	46.30 [a]
0.4 l/day	64.73[b]	35.27 [a]
1 l/day	64.75 [b]	35.25 [a]
2 l/ day	62.27 [b]	37.73 [a]
2 l/ 2nd day	68.95 [a]	31.05 [b]
2 l/week	61.50 [c]	38.50 [a]

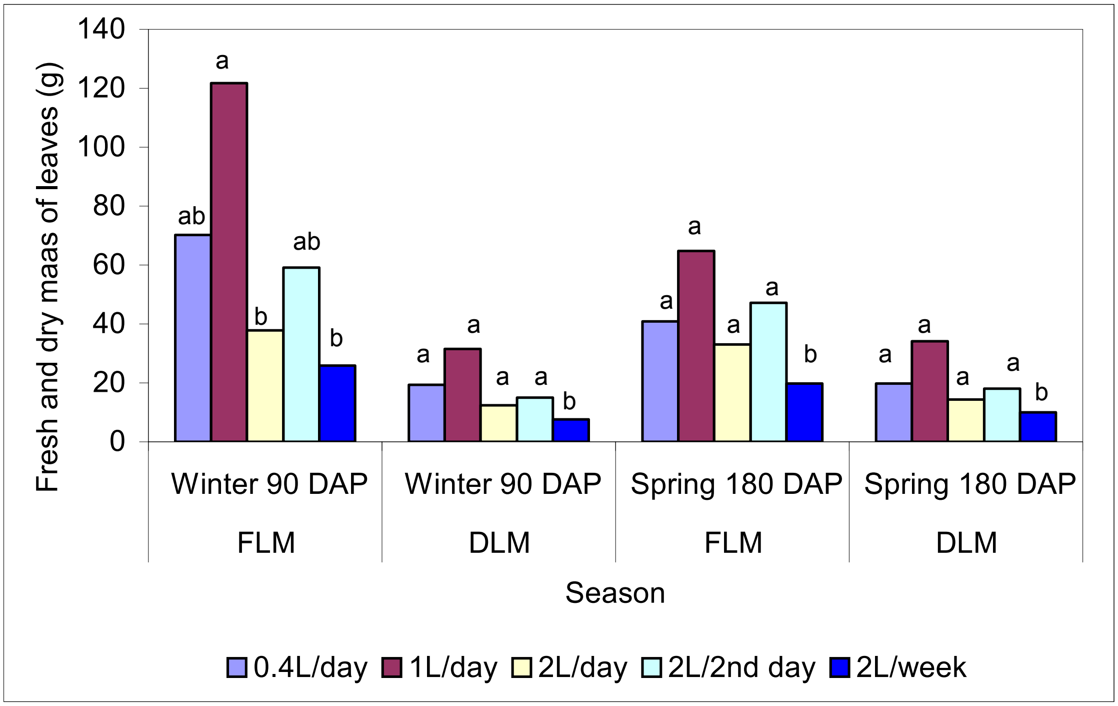
Values with the same letters are not significantly different, P≤0.05



Treatment means with letters in common are not significantly different at P≤0.05

Figure 4.24 Fresh and dry mass of leaves of bush tea as influenced by growing media at 90 and 180 days after planting (DAP); FLM = fresh leaf mass; DLM = dry leaf mass

At 90 DAP (winter), plants that received a fertigation frequency of 1 ℓ/day had greater fresh leaf mass compared to plants that were fertigated with 2 ℓ/day and 2 ℓ/week (Fig. 4.25). Dry leaf mass was lowest from plants fertigated with 2 ℓ/week compared to the rest of the fertigation frequencies, which replicates a typical dry climate. Similar results were obtained at 180 days after planting.



Treatment means with letters in common are not significantly different at P≤0.05

Figure 4.25 Fresh and dry mass of leaves of bush tea as influenced by fertigation frequency at 90 DAP and 180 DAP. DAP = days after planting; FLM = fresh leaf mass; DLM = dry leaf mass

4.4 DISCUSSION

According to the literature *Athrixia phylicoides* is a shrub that could reach 1 m in height, with leafy stems during this growing period. This shrub will flower throughout the year depending on the area but the best flowering time is from March to May. The winter harvest (90 days after planting) was made of plants grown over the autumn season and the spring harvest (180 days after planting) was made of plants grown over the winter season.

Different fertigation frequencies and the growth media are known to influence growth and development of many plant species. According to the results from the different harvesting periods, it was observed that bush tea grew faster from the summer to the autumn season than from winter to spring season. Sand and pine bark and different fertigation frequencies (0.4 ℓ/day, 1 ℓ/day, 2 ℓ/day, 2 ℓ/2nd day and 2 ℓ/ week) showed significant effects on growth performance and yield of bush tea. However, the interaction of growing media and fertigation frequencies had no significant effect on the plant, except for dry root mass. The interaction showed that plants which were fertigated with 1 ℓ/day and 2 ℓ/2nd day in sand had significantly higher dry root mass at 180 DAP compared to those in pine bark. Other interactions such as lower fertigation frequencies resulted in lower dry root mass. Therefore, too high and too low fertigation frequencies affect roots of sand and pine grown plants similarly. Results supported Handreck & Black (2005), in which they stated that growing media should provide plants with nutrients, water and a growing environment. In addition, a good hydroponics medium should support the plant in the system, absorb and retain moisture, be porous to allow air circulation and provide proper drainage, and protect plant roots from temperature extremes (Niederwieser, 2001).

The pine bark pH of 5.7 used in this experiment was slightly acidic (Table A 2.2, p. 93). And at the end of the trial pH decreased to an average of 4.6 (acidic soil). The pH of sand growing medium was 6.9 at planting time and at the end of the experiment, the pH decreased to 6.5. The pH of both growing media thus decreased over time, but according to Handreck & Black (2005) and Niederwieser (2001) it is still acceptable for open-hydroponics production. Soil analysis results of the soil samples taken from the natural growing area of the plant also showed that the plants grew in the pH range of 5.6 to 6.1. My observation was that the pine bark medium might have been too acidic, which might have had an effect on the poorer plant growth performance. Bark also contains various organic compounds, such as phenolics and tannins, which are biologically active at low concentrations, that may reduce plant growth and which might be toxic or harmful to other plants (Ansermino *et al*., 1995, Reis *et al*., 1995). Testing these compounds was not done for this trial.

According to Young and Fox (1982) and Roberts (1990), bush tea may grow up to 1 meter tall. This finding was confirmed during the trial. The results showed that plants grown in sand were taller than 1 meter (1.06 m). The reason why bush tea performed better in sand than in pine bark could be related to the water holding capacity and air aeration properties of the different growth media (Hartman & Kester, 1983). Harvested bush tea plants were smaller from the pine bark growth media compared to those from the sand growth medium. This might be because of water logging, and more carbon dioxide in the pine bark medium (Hartman & Kester, 1983). Similar results were found by Mpati (2005) on the response of fever tea (*Lippia javanica)* to growth media in which sand grown fever tea plants were taller compared to pine bark grown plants.

Avener (2003) indicated that increasing daily fertigation frequency induced significant increases in yield of greenhouse crops. Thompson, White, Walworth & Sower (2003) are also in agreement with the results found on the crops in which a higher frequency of fertigation resulted in an increase in plant height. In this experiment, low fertigation frequencies resulted in lower yields, probably due to the deficiency of nutrients rather than of water according to Avener (2003) and that a high fertigation frequency could balance out the nutrient deficiencies. On the other hand, with the 2 ℓ /week application, insufficient amount of water and an excess of fertilizer application could lead to a build up of soluble salts, which will also affect the growth of the plant (Ku & Hershey, 1996) and this could be seen in Table A 2.3. The results were in agreement with Ku and Hershey (1996), in which they reported that over-fertilization could greatly reduce plant quality and growth. To obtain optimum plant heights of bush tea, it is advisable to use of sand media and a fertigation frequency of 1 ℓ/day should be applied. In terms of total plant yield, plants grown in sand had significantly higher total fresh and dry mass compared to those of pine bark in both seasons. High plant yields were also obtained from plants that received an optimum fertigation frequency of 1 ℓ/day, compared to fertigation frequencies of 2 ℓ/day, 2 ℓ/2nd day and 0.4 ℓ/day.

The stem diameter of all the plants doubled in thickness from winter to spring harvest, which shows good growth performance. Plants tended to have thicker stems when grown in sand media compared to pine bark grown plants. This could be due to the lower number of stems from sand grown plants, thus more carbohydrates were available and could have led to thicker stems. Similar results were found by Mpati (2005), where her results showed that fever tea (*Lippia javanica*) plants grown in sand had thicker stems than pine bark grown plants. Although our results for stem diameter were not significantly different, the fertigation frequency of 1 ℓ/day again resulted in plants with slightly thicker stems than the other fertigation frequencies.

Growing media and fertigation frequency influenced the growth performance of bush tea plant. During the first season (winter) and second season (spring), the sand media plants produced a higher fresh and dry mass of leaves, stems and shoots and roots than those from the pine bark grown plants, even though the pine bark tended to produce more stems and shoots than the sand grown plants. Plants that received 1 ℓ per day produced a higher number of stems as compared to other fertigation frequencies, which seems to be optimal. The higher fertigation frequency (2 ℓ/day) may have led to poor oxygen supply to the roots and consequently retarded above plant growth. In most of the fertigation frequency graphs it was observed that 2 ℓ /week was insufficient for a good growth performance of bush tea plants.

Hartmann & Kester (1983) mentioned that a sand media must be sufficiently porous so that excess water drains, thus always permitting adequate penetration of oxygen to the roots. Sand grown plants had a higher root mass as compared to those of pine bark grown plants during both seasons. However, at the second season harvested plants grown from pine bark had longer roots as compared to sand grown plants. More branched roots were also observed from pine bark plants than from sand grown plants. The results were in agreement with Hartmann & Kester (1983), in which they reported that when sand is used as growing media in some plant species, the roots were coarse and non-branched. There were no significant differences on root length between the plants that received a fertigation frequency of 0.4 ℓ/day, 2 ℓ/day, 2 ℓ/2nd day and 2 ℓ /week at 90 DAP. At 180 DAP, there were also no significant differences in root length of plants that received a fertigation frequency of 2 ℓ/day, 1 ℓ/day and 2 ℓ/2nd day. However, plants that received a fertigation frequency of 1 ℓ/day had longer roots (137.9 mm) as compared to those of plants that received a fertigation frequency of 2 ℓ/week. It is noted that the root length of plants from the low fertigation frequency decreased to such an extent over time compared to the higher fertigation frequencies that one can assume that drought stress might have occurred.

Young and Fox (1982) and Roberts (1990) stated that bush tea flowers from May to July. In this trial it was found that the flowering period was extended when cultivating bush tea plants. These plants flowered from May to August under the tunnel. It was also noted that flowers were first noted on sand grown plants. Similar results were found by Sant, Selmer-Olsen, Gislerod and Solbraa (1984), where their results showed that when chrysanthemum cut flowers were grown in a composted bark, the plants showed delayed flowering compared to those in sand. Plants that received a fertigation frequency of 1 ℓ/day had non-significantly higher flower fresh mass compared to the other fertigation frequencies. It was, therefore, concluded that an application of 1 ℓ/day was an ideal frequency for flower production of bush tea. In this study it was observed that flowering period was affected by the treatments. This reason explains why sand grown plants produced more flowers overtime. Therefore, when further studies are conducted, more intervals for data collection should be included. It is also not advisable to cut back the plant after winter since plants do not recover.

4.5 CONCLUSIONS

Bush tea can be cultivated under semi-controlled environment such as in a poly-ethylene covered plastic tunnel. Optimum plant yield and height was recorded, which implies that effective cultivation of this species is feasible. Bush tea can grow up to 1m tall in sand. The cultivation and growth performance of bush tea was affected by treatments such as growing medium and fertigation frequency. In overall, sand growth medium was superior for plant stem and shoot mass, leaf mass, root mass and flower mass compared to pine bark. Plants that received insufficient amount of water (2 ℓ /week) resulted in stunted growth and produced a poorer yield of bush tea plant. An application of 2 ℓ/day was also too high for bush tea. An optimum application of 1 ℓ/day is ideal for growth and performance of bush tea as the plant grew better under this fertigation frequency.

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CHAPTER 5

GENERAL DISCUSSION AND CONCLUSIONS

Bush tea (*Athrixia phylicoides)* is classified as an indigenous plant in South Africa and is commonly known as bush tea or bushman tea (Gericke, 2002). Botanically, it is an attractive shrub, about 50 cm to 1 m in height, branched, with thin woolly stems. Bush tea is a medicinal herbal tea, used for cleansing or purifying the blood, treating boils, bad acne, infected wound and cuts (Mabogo, 1990; Swanepoel, 1997). Herbal tea prepared from this plant is well studied by several people and has proven to be a good quality tea. The infusion from leaves of bush tea is drunk as a tea and is believed to have aphrodisiac properties (Roberts, 1990). In the Limpopo Province of South Africa, the stems are tied up in bundles and traded on small-scale as a broom for sweeping (Mabogo, 1990). Traditional medicinal plants, such as *Athrixia,* need to be conserved and managed on a sustainable basis, because the South African population is still depending on them (Swanepoel, 1997). The conservation of bush tea, as addressed in this dissertation, was investigated in terms of gathering the indigenous knowledge and practices on cultivation of this medicinal plant.

In Chapter 3, a survey was conducted on the indigenous knowledge of bush tea. The results from the survey indicated that people from the area of study possessed a remarkable knowledge about the plant and its uses. They have been using the plant for decades as a medicine, for making brooms and drunk as a healthy tea. The results from the respondents indicated that bush tea is over-harvested without any obligation to propagate it. The results also make it clear that anyone can harvest the plant without difficulty. It was also clear that the respondents do not request any permission to harvest it. In addition, they were not keen in propagating this plant for conservation purposes. Due to the fact that bush tea is readily available and that the respondents may use other medicinal plants to replace the bush tea plant, majority of respondents showed no interest in propagating the plant for themselves. If one observes how it is harvested, it clearly shows that there is mechanical damage to the plant during this process. For example, respondents indicated that sometimes they remove the roots without uprooting the plant. The plant can be uprooted from the soil when is harvested, but then the respondents do not plant anything back.

One needs to understand the impact of harvesting and one needs to promote the multiple uses of this plant. There is a need to show the respondents on how to propagate this plant so that it could be conserved. Conservation, propagation and cultivation of medicinal plants are essential, because in future there will be a huge demand for this plant on the market.

With the cultivation trial in Chapter 4, it was discovered that bush tea could be cultivated successfully in a semi-controlled environment, in this case in a poly-ethylene plastic covered greenhouse tunnel. Superior growth performance of this plant was achieved when a drip system was used to fertigate the plants (open-hydroponic system). The trial showed that plants definitely performed better in sand as opposed to pine bark. The results also indicated that the plant should be grown in sand and under a fertigation frequency of 1 liter per day to improve growth and yield.

Another significant observation made during the trial was that flowering was earlier and longer than noted in the literature. It was observed that plant growth decreased from summer to winter season, and this could be because the plant was preparing itself for dormancy. Bush tea in the field normally grows vigorously and after flowering, the above ground parts normally dies off and the plant generates new shoots during the springtime. At 180 DAP (spring), which was about three months after winter, dead plant materials caused by winter cold season were cut back in order to generate new shoots. Unfortunately, most of plants did not survive this practice. We decided to include this practice, as the local people in Venda harvest the flowering stem just after winter. Looking at the commercial side, similar pruning techniques have been used in the cultivation of cut roses. This practice is therefore not recommended when bush tea is grown on a commercial scale in a tunnel.

Growing media influenced the number of flowers and their fresh and dry mass. Sand grown plants had more flowers compared to pine bark grown plants during harvest. For the people who want to use this plant as a flowering ornamental shrub/cut-flower, it is advisable to grow bush tea in a sand growing media. It was also found that after flowering, plant growth ceased, thus the plants tended to shed their leaves and most of the above ground plant parts died off. According to the literature, bush tea flowers from May to July. However, it was observed from the results that flowering period also extended until August. Flowers were first noted in early May (beginning of winter). Plants that were fertigated with a moderate amount of water (1 liter per day) had more flowers than any other fertigation frequency.

Neither growing media nor fertigation frequencies had a significant effect on the stem diameter of bush tea. It was, however, noticed that when the plant grew the stem width also increased.

Our trial showed that during the autumn season the plant produced more leaves than in any other season. Based on the results from the survey study, it was indicated that a majority of the respondents frequently harvested the leaves for medicinal purposes during that period. Therefore, it is advisable that less stem harvesting should take place during the autumn season to enable the plant to build photosynthetic material to grow and survive during the winter. It is at this time of season where healthy and green leaves are produced. It is recommended the leaves be harvested just before the flowers commence (winter) for medicinal and tea purposes, as during this season more mature leaves are produced.

With the results from this study, I suggest that a fertigation frequency of 1 ℓ/day should be optimal under this specific environmental condition for high plant growth performance. According to Avener (2003), low fertigation frequencies may result in lower yields, due to a deficiency in nutrients and that an increase in fertigation frequency could balance out nutrient deficiency. In our trial, it was important to note that plants that received the lowest amount of water (2 ℓ/ week) experienced drought stress which led to lower production of leaves and stems. On the other hand, the highest amount of 2 ℓ/ day also negatively affected the overall growth performance. In this case, too much water during the growing period probably caused oxygen deficiency.

For small scale or resource poor farmers and herbalists or traditional healers who wish to grow bush tea, it is recommended and advisable to cultivate bush tea in a semi-controlled environment. Although the sand media is difficult to work with because it is very heavy compared to pine bark, I suggest to use this growing media for cultivation of bush tea under semi-controlled environment, as it is a cheaper solution compared to other growth media. In addition, fertigation of a frequency of 1 ℓ/day is recommended under this specific environmental and growing condition for optimal plant growth performance.

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CHAPTER 6

GENERAL SUMMARY

Bush tea is a plant that has been used for many years for cleansing or purifying of the blood, treating boils, headaches, infested wounds, cuts and the solution may also be used as a foam bath. This plant is mainly harvested in the wild where the population is declining due to over- exploitation. Besides its medicinal properties, bush tea is used to make traditional brooms and can also be potentially used as an ornamental cut-flower. The plant can be propagated through seeds and cuttings. The conservation of this species needs urgent attention. Therefore, a questionnaire survey was conducted in selected villages in Venda, Limpopo Province in order to validate the many uses of this plant. In addition, a tunnel experiment was carried out to investigate two growing media (pine bark and sand) as well as different fertigation frequencies (0.4 ℓ/day, 1 ℓ/day, 2 ℓ/day, 2 ℓ/2nd day and 2 ℓ/ week) on growth and yield of bush tea.

The aim of the survey was to gain knowledge from traditional healers, street sellers and bearers of indigenous knowledge on bush tea. The survey study was, therefore, conducted in order to collect the most important indigenous knowledge of the bush tea plant from the local people in Venda. Questionnaires, which were formulated, contained questions: about the indigenous knowledge of the plant, propagation, harvesting and methods for preparing medicine and tea. People in the area of study know the plant as *bostee*. Bush tea is easily available to users. However, the plant faces the danger of over harvesting by the users for various reasons. The majority of the respondents had an interest to propagate the plants. Bush tea is used as a medicine, herbal tea and also for making brooms. It was indicated that leaves and stems are mostly used. The plant is harvested by cutting the stems from the base. Roots are also used for medicinal purposes. Due to this, bush tea faces the danger of exploitation and over harvesting by the users.

The infusion of the plant (leaves and branches) is boiled and drunk as a tea with sugar. They believe that the tea is excellent for coughs, headaches, stomachache and flu. The infusion of the plant is used to clean the blood, kidney, womb, and veins. Bush tea is also used for its aphrodisiac properties. The extract from the plant is excellent for lowering the blood pressure, for diabetes and heart related diseases. Judging from the keen response from the respondents, it is clear that bush tea will always play a major role in their lives as a source of their income, as a medicine or herbal tea. The question is how to sustain this plant?

For the cultivation trial, 200 plants were grown in either sand or pine bark growing media in different fertigation frequencies (0.4 ℓ/day, 2 ℓ/day, 2 ℓ/2nd day and 2 ℓ /week) from January 2003 until November 2003. Plants were harvested destructively in winter and spring season. Plants grown in sand growing media showed better performance than pine bark grown plants in terms of plant height, number stems, shoots, leaves, roots and flowers. Sand grown plants had a higher fresh and dry mass of leaves, stems and roots than those from the pine bark. However, pine bark produced a higher number of stems than the sand grown plants. Growing media influenced the number of flowers and fresh and dry flower mass. Important information in this trial was that the flowering period of this plant was extended when cultivated under tunnel conditions. Sand grown plants had more flowers compared to the pine bark grown plants during spring harvest.

Plants that received insufficient amounts of water (2 ℓ /week) resulted in stunted growth. Plants that received 1 ℓ per day produced a higher number of stems, shoots, fresh and dry mass compared to those of other fertigation frequencies. The highest amount of fertigation frequency (2 ℓ/ day) was too much for the growth of bush tea. Plants that received the lowest fertigation frequency led to poor performance in terms of growth and yield. The best growth performance was found in plants grown in sand compared to pine bark grown plants, receiving 1 ℓ of fertigation per day.

This dissertation documents an investigation survey on the indigenous knowledge and cultivation of the bush tea plant. It also provides valuable and much needed information for the cultivation and indigenous knowledge of this medicinal herbal tea for subsistence farmers and commercial farmers. This dissertation also provides the important data for floriculture as a possible ornamental cut- flower. Generally, this dissertation provides information for the potential conservation and utilization of this remarkable medicinal plant.

APPENDIX 1: Question

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For office use

Answer each question by circling the appropriate number in a shaded box, or write your answer in the space provided.

V1 [ ][ ][ ] 1-3

A. Respondent's Profile

1. What is the title of your job position?

Traditional healer	1
Street seller	2
IKS person	3

V2 [ ] 4

V3 [ ] 5

V4 [ ] 6

2. In which village do you live?

V5 [ ][ ] 7-8

3. What is your age?

Younger than 40 years	1
Forty years and older	2

V6 [ ] 9

4. What is your gender?

Male	1
Female	2

V7 [ ] 10

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5. What is your highest a

No school	
Grade (1-7)/Standard (1-5)	2
Grade (8-12)/ Standard (6-10)	3
Other (specify)	4

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V8 ☐ 11

B. *Traditional knowledge of bush tea plant*

6. Do you use or sell the plant?

Yes	1
No	2

V9 ☐ 12

7. What is the traditional name of this plant?

V10 ☐☐ 13-14

V11 ☐☐ 15-16

V12 ☐☐ 17-18

V13 ☐☐ 19-20

8. Where do you get the plant materials from?

Bush	1
Cultivate	2
Bush/cultivate	3
N/A	4

V14 ☐ 21

9. What are the uses of tl

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V15		22-23
V16		24-25
V17		26-27
V18		29-30

10. Which plant parts do you use?

Leaves
Roots
Stems
Whole plant

V19		31
V20		32
V21		33
V22		34

C. *Propagation information on bush tea plant*

11. Do you grow the plant for yourself?

Yes	1
No, but would like to grow it	2
No ,and don't want to grow it	3

V23		35

12. If you propagate the plant, which plant parts do you use to propagate bush tea?

Roots	1
Cuttings	2
Seeds	3

V24		36
V25		37
V26		38

13. Would you be interested to buy if somebody else grows the plant for you?

Yes	1
No	2

V27		39

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14. Would you be interested to grow the plant for yourself if one shows you how to grow it?

Yes	1
No	2

V28 [ ] 40

D. Harvesting and post harvest handling

15. How is the plant harvested?

Cut the whole plant	1
Uproot	2
Cut only the leaves and branches	3

V29 [ ] 41
V30 [ ] 42
V31 [ ] 43

16. From which areas do you harvest bush/Zulu tea?

Mountains	1
Hills	2
Field	3

V32 [ ] 44
V33 [ ] 45
V34 [ ] 46

17. What is the distance from where you get the plant in kilometers?

V35 [ ][ ] 47-48

18. How much is the traveling cost from where you get the plant?

R

V36 [ ][ ][ ] 49-51

19. When do you harvest the plant for broom making?

Before flowering	1
After flowering	2
Don't use the plant for broom making	3

V37 [ ] 52

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20. How often do you sel
the people?

Never	1
Seldom	2
Often	3

V38 ☐ 53

21. Which kind of ethnic group of people do you sell the medicine to?

Venda	1
Shangaan	2
White	3
Other (specify)	4

V39 ☐ 54
V40 ☐ 55
V41 ☐ 56
V42 ☐ 57

22. Which other plants do you sell for medicine?

V43 ☐☐ 58-59
V44 ☐☐ 60-61
V45 ☐☐ 62-63
V46 ☐☐ 64-65
V47 ☐☐ 66-67

23. How effective is bush tea to cure the following diseases?

	Very effective	Effective	Not effective
Heart problem	3	2	1
Diabetes	3	2	1
High blood pressure	3	2	1

V48 ☐ 68
V49 ☐ 69
V50 ☐ 70

24. What other diseases

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V51 71-72

V52 73-74

V53 75-76

V54 77-78

25. Are there any other plants that work the same as bush/ Zulu tea plant for medicine?

Yes	1
No	2

V55 79

26. If yes, what are they?

V56 80-81

V57 82-83

V58 84-85

V59 86-87

E. Tea and medicine preparation

27. Do you store the plant materials for medicinal purpose?

Yes	1
No	2

V60 88

28. When preparing the medicine, do you add anything else?

Yes	1
No	2

V61 89

29. How do you prepare the tea?

Like other teas	1
Boil the leaves	2

V62 90

For office use

30. If you boil the leaves, for how long do you boil the tea? (In minutes)

V63 [|] 91-92

31. Do you add anything else when preparing the tea?

Yes	1
No	2

V64 [ ] 93

32. If yes, specify?

V65 [ ] 94

V66 [ ] 95

V67 [ ] 96

33. Are there any other tea plants that you use as medicine?

Yes	1
No	2

V68 [ ] 97

34. If yes, what are they?

V69 [ ] 98

V70 [ ] 99

V71 [ ] 100

<u>Thank you for your co-operation</u>

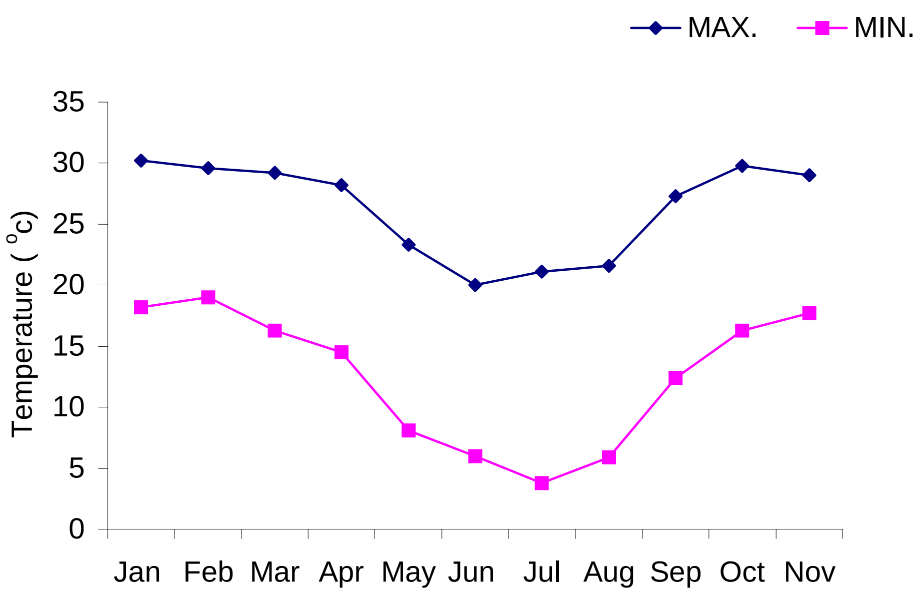

Figure A. 2.1 Minimum and Maximum temperatures during the trial in 2003

Table A. 2.1 Macro- and micro elements present in Feed –All (46) fertilizer

Macro-elements (g/kg)	
Element	**Quantity**
Nitrogen (N)	160
Phosphorus (P)	50
Potassium (K)	220
Calcium (Ca)	11
Magnesium (Mg)	3

Micro-elements (mg/kg)	
Element	**Quantity**
Boron (Bo)	335
Iron (Fe)	356
Zinc (Zn)	100
Manganese (Mn)	125
Molybdenum (Mo)	12.5
Copper (Cu)	12.5

Table A. 2.2 Analysis of bark before and after planting

		pH	EC	Ca	Mg	K	Na	P
			mS/m	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**
Before planting		5.7	161	50.1	48	252.5	27.8	
After harvest	**2 ℓ/day**	4.5	75.5	38.5	28.5	109.3	52.7	18.5
	1 ℓ/day	4.9	45.5	10.7	2.9	106.7	41.6	16.3
	0.4 ℓ/day	4.4	143	78.5	58.6	170.3	60.3	33.2
	2 ℓ/2nd day	4.7	102.6	43.9	23	142.4	50.5	30.5
	2 ℓ/week	4.7	54.4	16.1	5.5	109.5	33.5	11.8

Table A. 2.3 Analysis of sand medium before and after planting

		pH	P Bray	Ca	K	Mg	Na
			mg/kg	**Mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**
Before Planting		6.9	1.4	93	36.4	4	15
After harvest	**2 ℓ/day**	6.3	28.9	36	61	12	72
	1 ℓ/day	6.2	34.	51	84	13	78
	0.4 ℓ/day	6.7	69.6	65	140	18	102
	2 ℓ/2nd day	7	30	48	56	9	75
	2 ℓ/week	6.7	35.9	77	76	17	74

Table A.2.4 Amount of fertilizer applied per week

Element	2 ℓ/day	1 ℓ/day	0.4 ℓ/day	2ℓ/2nd day	2 ℓ/week
			Macro-elements (g/week)		
N	2.24	1.12	0.45	0.96	0.32
P	0.70	0.35	0.14	0.30	0.10
K	3.08	1.54	0.62	1.32	0.44
Ca	0.15	0.08	0.03	0.07	0.02
Mg	0.04	0.02	0.01	0.02	0.01
			Micro-elements (mg/week)		
Br	4.69	2.35	0.94	2.01	0.67
Fe	4.98	2.49	1.00	2.14	0.71
Zn	1.40	0.70	0.28	0.60	0.20
Mn	1.75	0.88	0.35	0.75	0.25
Mo	0.18	0.09	0.04	0.08	0.03
Cu	0.18	0.09	0.04	0.08	0.03

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Table A.3.1 Analysis of variance for plant height, root length, number of shoots and stems of bush tea at 90 days after planting

Source of variation	DF	Mean squares [z]				
		Plant height (mm)	Root length (mm)	No. of shoots	No. of stems	Stem diameter (mm)
Fertigation frequency (I)	4	269.36 NS	1671.67 NS	1049.00 NS	233.21 NS	398.63 NS
Medium (M)	1	728.97 *	749.07 *	35.27 NS	1815.00 *	248.07 NS
I*M	4	372.56 NS	31.98 NS	455.26 NS	251.79 NS	269.60 NS
Error	45	225.76	166.84	247.17	265.96	268.49

[z]F-value significant (*), highly significant (**) or NS (not significant) at 5 % level of probability

Table A.3.2 Analysis of variance for fresh mass of plant, root, stem and leaf mass of bush tea at 90 days after planting

Source of variation	DF	Mean squares [z]			
		Fresh mass (g)			
		Plant	Root	Stem	Leaf
Fertigation Frequency (I)	4	674.19 NS	1766.87 NS	1406.66 NS	1658.17 NS
Medium (M)	1	831.33 NS	1595.45*	610.51 NS	2025.48**
I*M	4	202.59 NS	119.31NS	14.16 NS	51.98 NS
Error	42	240.38	99.26	164.00	111.07

[z]F-value significant (*), highly significant (**) or NS (not significant) at 5 % level of probability

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Table A.3.3 Analysis of variance for dry mass of plant, root, stem and leaf mass of bush tea at 90 days after planting

Source of variation	DF	Mean squares ^{z}			
		Dry mass (g)			
		Plant	Root	Stem	Leaf
Fertigation frequency (I)	4	1766.13 ^{NS}	1597.18 ^{NS}	1026.01 ^{NS}	1421.20 ^{NS}
Medium (M)	1	1078.62*	1942.78**	46.95 ^{NS}	1572.59 *
I*M	4	126.66 ^{NS}	137.01 ^{NS}	104.69 ^{NS}	111.36 ^{NS}
Error	42	113.79	109.86	208.69	134.93

^{z}F-value significant (*), highly significant (**) or NS (not significant) at 5 % level of probability

Table A.3.4 Analysis of variance for fresh plant, root, stem and leaf mass of bush tea at 180 days after planting

Source of variation	DF	Mean squares ^{z}			
		Fresh mass (g)			
		Plant	Root	Stem	Leaf
Fertigation frequency (I)	4	2.32 ^{NS}	1.96 ^{NS}	2.17 ^{NS}	1.95 ^{NS}
Medium (M)	1	3.12*	2.53*	2.59 ^{NS}	0.10 ^{NS}
I*M	4	0.72 ^{NS}	1.75 ^{NS}	0.83 ^{NS}	0.42 ^{NS}
Error	35	0.62	0.53	0.67	0.58

^{z}F-value significant (*), highly significant (**) or NS (not significant) at 5 % level of probability

Table A.3.5 Analysis of variance for dry plant, root, stem and leaf mass of bush tea at 180 days after planting

Source of variation	DF	Mean squares [z]			
		Dry mass (g)			
		Plant	Root	Stem	Leaf
Fertigation frequency (I)	4	2.30 NS	2.20 NS	2.90 NS	2.65 NS
Medium (M)	1	2.92*	3.83*	2.73*	0.09 NS
I*M	4	0.75 NS	1.87*	0.77 NS	0.65 NS
Error	35	0.65	0.48	0.65	0.62

[z]F-value significant (*), highly significant (**) or NS (not significant) at 5 % level of probability

Table A.3.6 Analysis of variance for plant height, root length, number of shoots, stems and stem diameter of bush tea at 180 days after planting

Source of variation	DF	Mean squares [z]			
		Plant height (mm)	Root length (mm)	No. of shoots	No. of stem
Fertigation frequency (I)	4	3.63 NS	0.95 NS	1.09 NS	0.87 NS
Medium (M)	1	4.42*	0.12 NS	0.03 NS	0.03 NS
I*M	4	0.27 NS	0.64 NS	0.99 NS	1.13 NS
Error	35	0.60	1.06	0.99	1.06

[z]F-value significant (*), highly significant (**) or NS (not significant) at 5 % level of probability

Table A.3.7 Analysis of variance for number of flowers, fresh and dry flowers mass and as well as plant stem diameter of bush tea at 180 days after planting

Source of variation	DF	Mean squares ^{z}			
		Number of flowers	Fresh flowers mass(g)	Dry flowers mass (g)	Stem diameter (mm)
Fertigation frequency (I)	4	0.43 ^{NS}	0.36 ^{NS}	0.28 ^{NS}	0.95 ^{NS}
Medium (M)	1	4.30 *	4.68 *	4.59 *	1.51 ^{NS}
I*M	4	0.34 ^{NS}	2.54 ^{NS}	0.47 ^{NS}	1.22 ^{NS}
Error	24	0.89	18.73	0.86	0.97

^{z}F-value significant (*), highly significant (**) or NS (not significant) at 5 % level of probability