DOMESTICATION OF *ARTEMISIA AFRA* (AFRICAN WORMWOOD) AND PROPAGATION BY LEAFY STEM CUTTINGS

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DOMESTICATION OF *ARTEMISIA AFRA* (AFRICAN WORMWOOD) AND ROPAGATION BY LEAFY STEM CUTTINGS

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A Dissertation submitted in partial fulfillment of the requirements for the Degree of Master of Agriculture in the Faculty of Agricultural and Environmental Sciences of the University of Fort Hare.

FEBRUARY 2002

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DECLARATION

I hereby declare that this dissertation represents my own work both in conception and execution and has not been submitted to any other University.

Signed ....

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ACKNOWLEDGEMENTS

My appreciation extends to the following people who have contributed to the completion of this study:

- Mr. M.O. Brutsch, my supervisor for his advice, encouragement and tolerance.
- Dr. P. Soundy who advised me for the Masters programme and organised the sponsorship.
- National Research Foundation (NRF) for financial assistance.
- Mr. O. Zweni and University of Fort Hare farm workers who assisted me during my experiments.
- Prof. P.N.S. Mnkeni who helped me with the statistical analysis of my experimental results.
- Mr. Williams for assistance with analysing results of the questionnaire survey.
- Mrs. Suzzette Oosthuizen (librarian) who cooperated in providing information needed for my study.
- Gratitude is expressed to my father (Mr. V.W. Ketelo), mother (Mrs. N.L. Ketelo), brother (M.W. Ketelo), sisters (N. Ketelo and N.A. Ketelo) and my entire family.
- I thank my sister, T.D. Ketelo for her efforts to bring me to University.
- Mr. M.M.M. Duka who advised me to study agriculture.
- My friends, V.N. Mhlanga, M. Tola, H.W. Mandlana, and M. Nkibi for mutual sharing of problems and encouragement.
- Most importantly, I thank the almighty GOD for giving me strength, courage and inspiration during the difficulties I encountered throughout my education.

ABSTRACT

DOMESTICATION OF *ARTEMISIA AFRA* (AFRICAN WORMWOOD) AND PROPAGATION BY LEAFY STEM CUTTINGS

Artemisia afra (African wormwood) is used traditionally as medicinal plant to cure fever, coughs, colds and headache by indigenous people. The objectives of this study were two-fold. Firstly, to determine how local rural people feel about the domestication of Mhlonyane for the extraction of essential oil. This was done by means of a questionnaire survey, where 80 respondents were selected at random at Melani village in the Nkonkobe District of the Eastern Cape. Secondly, preliminary trials were conducted at the University of Fort Hare on the vegetative propagation of *Artemisia afra* using leafy stem cuttings rooted under an intermittent mist spray using different Indolebutyric acid (IBA) treatments and different rooting media. Also, tested were the growth retardant paclobutrazol (PBZ) and some fertilizer treatments for growing on the rooted cuttings in pots.

The questionnaire survey revealed that local people were largely familiar with uses Mhlonyane, but were not familiar with the oil that could be extracted from it by distillation. Few people cultivated the plant and nobody used vegetative propagation. There was interest in cultivating *A. afra* for industrial essential oils if it could create employment and improve the socio-economic situation in the region. The Melani people would be able to benefit from the essential oils experience of the nearby University of Fort Hare and the proximity of a commercial farmer with experience of distillation and the marketing of essential oils.

Vegetative propagation is preferable to sexual propagation to perpetuate clones of desirable essential oil crops. Leafy stem cuttings can be propagated successfully in cavity trays under intermittent mist, where they root equally well when treated with IBA in the form of Seradix® No.1 or Seradix® No.2, being

different concentrations of IBA in powder formulation. Palm peat alone or in a mixture of 1:1 (v/v) with sand gave significantly better results than when sand was used alone because the latter did not give as good a root development and the "plug" disintegrated easily on being removed from the cavity trays.

For growing rooted cuttings in pots, Hygromix®, a commercially available seedling mix, proved superior to soil as a growing medium. The soil had poorer physical properties which lead to poor drainage and poorer growth of the rooted cuttings.

A preliminary trial with PBZ alone or in combination with IBA showed potential benefits of PBZ, not only for improved rooting but also for the improved health of the treated cuttings.

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1. INTRODUCTION

Southern Africa has many aromatic plants, most of which are unpalatable to livestock owing to their essential oil content, which is located primarily in leaf glands. As a number of these species contain and yield economic amounts of essential oil used in the perfume industry their status as alternative crops should be considered. Plants that have potential as alternative crops include *Aloe ferox*, *Pteronia incana*, *Tagetes minuta*, *Salvia stenophylla*, *Eriocephalus punctulatus*, *Lippia javanica*, *Leonotis leonurus* and *Artemisia afra* (Webber, Magwa and van Staden, 1999).

Artemisia afra (African wormwood, Lanyana or Mhlonyane) is indigenous to some of the mountain regions of Southern Africa (Graven, Gardner and Webber, 1988). It is found in well-watered areas and is fairly abundant in parts of the Amatola foothill areas, being the only widespread species of this genus in the Keiskammahoek and Hogsback areas of South Africa (Jakupovic, Klemeyer, Bohlmann and Graven, 1990). It is a bushy, branched perennial shrub, which grows up to a meter in height. It has thin browning bark and grey-green leaves which are very aromatic when crushed. It possesses characteristic paniculate aggregations of pale yellow inflorescences. It has a powerful top note with a fresh and penetrating cineole-camphor note, followed by a spicy note.The major constituents of the oil are: thujone (52%), isothujone (13%), 1.8-cineole (13%), Camphor (6%) and artemisia ketone (Graven *et al.*, 1988).

Artemisia afra is used as an alternative for the bitter flavours in armoise or wormwood oils. It is also used as alternative to wormwood/ armoise, as a fragrance component in toiletries, cosmetics and perfumes. Its oil has been shown to be a very effective antimicrobial agent against certain bacteria and fungi as well as possessing an antioxidant effect. This plant is one of the most widely used Southern African medicinal plants. Traditionally it is used for a whole range of conditions including colds, headaches, diabetes mellitus, bronchial complaints and stomach disorders. The leaves are used as a tea, in a bath, as a leaf poultice or the vapours from boiling leaves are inhaled. It has also been used extensively as an insect repellent and anthelmintic (Graven *et al.*, 1988).

Artemisia afra as an essential oil plant can provide a new source of income for rural people, without demanding high levels of inputs. The plant material in its raw state is not of any great value and will not be stolen, nor it is palatable to livestock (Graven *et al.*, 1988).

To produce a plant which is genetically identical to the mother plant, clonal (vegetative) propagation methods are needed. For example propagation by stem cuttings (adventitious root formation), root cuttings, stooling, layering, grafting and budding are techniques that can produce the desired clones. The selection of the method is dependant upon the plant variety. Propagation from seed, while suitable for many plants, especially annuals, often produces variable progenies.

Plants propagated from cuttings have the same characteristics as the parent plant. The rapid generation of adventitious roots is necessary for the plant to transport water and necessary essential nutrients from the medium. Root formation will be enhanced by using selected plant material at the right time, by treating it with appropriate root-promoting growth substances and by rooting under favourable conditions.

The objectives of this study were two-fold:

- To determine how rural people in the Eastern Cape feel about the domestication of African wormwood (Mhlonyane) for the extraction of essential oils.
- To study the vegetative propagation of the plant using stem cuttings. This should include the testing of different Indole Butyric Acid (IBA) treatments, different rooting media and fertilizers and the use of Paclobutrazol (PBZ), a growth retardant.

2. LITERATURE REVIEW

According to Graven, Webber, Venter and Gardner (1989), *A. afra* is a perennial woody member of the compositae family and occurs throughout Southern Africa, including the well-watered areas of the Eastern Cape. It is closely related to European wormwood (A. *absinthium*). A brief review of *A. afra* as an essential oil plant follows as also a review of different types of stem cuttings and factors affecting rooting.

2.1 *Artemisia afra* as an essential oil crop

Artemisia afra as an essential oil plant could provide a new source of income for rural people, without demanding high levels of inputs. The plant material in its raw state does not have any great value and will not be stolen, nor it is palatable to livestock (Graven, Gardner and Webber, 1987).

Graven *et al.* (1988) indicated that when *A. afra* is grown as a domesticated crop, it is inclined to produce tall, woody stems and shed a large proportion of its leaves before flowering in the autumn or winter. Distillation experiments have shown that the woody stems contain virtually no oil. But if *A. afra* is harvested and distilled in the vegetative stage in mid-summer, it recovers rapidly and produces a second growth that attains full flower in late autumn. Piprek, Graven and Whitfield (1982) (as cited by Webber, Magwa and van Staden, 2000) reported that leaving *A. afra* material in the shade for a period of 24 hours slightly increased the yield of oil per ton of fresh material. Graven *et al.* (1987) also reported that harvested *Eriocephalus punctulatus* plant material stored for a week before being processed yielded more oil.

Crop species with large seeds like maize (*Zea mays*), faba beans (*Vicia faba*) and peas (*Pisum sativum*) showed successful establishment in soil close to the *A. afra* shrubs (Materechera and Mbokodi 1997). This contradicts Hansen-Quartey (1995) who indicated that the very poor germination of maize and beans when planted in soils occupied previously by *A. afra* demonstrated the toxicity of soils under *A. afra* shrubs. Hansen-Quartey, Materechera and Nyamapfene (1998) found that selected soil samples from the bare patches beneath the canopy of *A. afra* had significantly higher stability of aggregates than the soil where *A. afra* had never been grown. The analysis they made from *A. afra* extracts indicated that it contained a mixture of unsaturated hydrocarbons, carboxyls and benzene. It was also believed that an increase in the introduction of *A. afra* could lead to reduction in soil erodibility on cultivated lands, and therefore, could be beneficial from both the economic and soil management stand points.

Webber *et al.* (2000) found that during the initial phases of the domestication programme, vegetative material from *Eriocephalus punctulatus* transported over a long distance (further than 10 km) using an open truck, traveling at about 100 km/h, there was a reduction in the oil content of the plant material. This was a major problem in the domestication programme because the oil yield per hectare from *E. punctulatus* is relatively low and the input costs are high.

Domestication of new crops is a process that cannot be achieved in a few years, but if successful the benefits can have a significant impact over many areas (Fletcher, 1998). There is increasing demand for economically viable livelihood options in rural areas in the world. The most obvious benefit of domestication of a new crop would be the development of processing, packaging and other activities that result in job creation and activate local rural communities (Janick, 1996; Imrie, Bray, Wood and Fletcher, 1997). Because new crops are raised first on relatively small acreages, local entrepreneurs can on a small scale carry out initial processing. Prior to any crop selection, knowledge is required of the micro-environment, the land, and water resources, natural flora and fauna, and local agricultural skills and problems (Lawrence, 1993).

Although some new crops may substitute for current crops in the market place, many new crops will have little or no displacement effect on current commodities. On the other hand, converting crop acreage into new industrial crops by decreasing production of major commodities may in the long term decrease the amount of agricultural subsidies required and will encourage the expansion of the manufacturing and industrial section associated with the food chain (Caplain, 1996).

Considerable variation occurs in the chemical components of Artemisia oil emanating from different geographic localities. The development of standard *A. afra* clones consequently appears to have much advantage. Such exclusive clones would enable local producers to compete even more effectively on the market against established essential oils and would permit the production of more uniform products. Considerable progress has been made in the selection and vegetative propagation of desired clones (Graven *et al.*, 1988).

2.2 Propagation of stem cuttings

Cuttings are parts of plants that are separated from the parent and treated in various ways to encourage the production of a complete plant, similar in all characteristics to the parent plant from which it was taken. Propagation by cuttings is the most important method of propagating ornamental shrubs, deciduous species as well as the broad and narrow-leaved types of evergreens. Cuttings are also used widely in commercial greenhouse propagation of many florists' crops, several fruit, vegetable and forestry species (Hartmann, Kester, Davies and Geneve, 1997). Fretz and Read (1979) reported that the number of woody ornamental plants propagated from cuttings far exceeds that propagated by seeds, layers, grafting or budding.

There are different types of cuttings and these include softwood, hardwood, semi-hardwood, and herbaceous cuttings. In all these types of cuttings, it is important for a propagator to apply appropriate management practices to maximize propagation. Some management techniques that need to be taken into consideration are selection and maintenance of stock plant, rejuvenation of stock plant, type of wood selected and seasonal timing. According to Evans and Blazich (1999), a removed portion of a plant such as stem or leaf undergoes severe stress. The severed tissue is immediately deprived of essential water and nutrients, and must depend upon stored energy and moisture while it re-establishes a system for obtaining water and capturing energy, and at the same time, carries on the regeneration of any missing organs. An understanding of the stress factors created consequently makes certain steps in the treatment of the cutting more predictable.

Rooting media must be considered an integral part of the propagation system for cuttings, in that the rooting medium is able to hold water and the cuttings during the rooting period (Hartmann *et al.*, 1997; Loach, 1988). Without proper environmental control, the rooting of many types of cuttings can be very difficult. Therefore tremendous variability in rooting, or in some cases complete failure of rooting, may occur if environmental conditions are not adequately controlled. These environmental conditions, which need to be taken care of, include suitable temperature, irradiance and water (Loach, 1988). It is important to maintain a film of water on the leaf surface at all times. Mist propagation helps in reduction of leaf temperature, and leads to reduced transpiration. According to Loach (1988) and Verma and Puri (1998), intermittent mist makes propagation possible under high light intensity and high rates of photosynthesis.

Using bottom heat in the rooting bench or propagating box may stimulate the initiation of adventitious roots or other missing plant organs. The bottom heat is used for both open and closed mist systems to counteract the low media temperatures induced by water (McConnell, Cruz, and Best, 1996).

2.2.1 Types of cuttings

Many different types of cuttings are available. However, their uses differ from plant to plant. In this study we focus on six types: hardwood stem cuttings, semi - hardwood, softwood and herbaceous stem cuttings, leaf cuttings and leaf-bud cuttings.

2.2.1.1 Hardwood cuttings

Hardwood cuttings are made from narrow-leaved evergreen species or leafless deciduous species like apples and pears. Only few types of hardwood cuttings have leaves and these must be rooted under moisture conditions that will prevent excessive drying, as they are usually slow to root, taking several months. Some species root much more readily than others. *Chemacyparis* and the low growing *Juniperus* spp. root easily and yews (*Taxus* sp.) root well, whereas the pines (*Pinus* sp.) and firs (*Abies* sp.) are more difficult to root. There is considerable variability among the different species in these genera concerning the ease of rooting of cuttings. Cuttings taken from young seedling stock plants root much more readily than those taken from older trees. Cuttings treated with indole butyric acid (IBA) at relatively high concentrations, root better (Rana, 1996).

Hardwood cuttings ordinarily are best taken between late autumn and late winter. It is quite important to handle cuttings rapidly after the material is taken from the stock plants. These cuttings must be rooted in a greenhouse with relatively high light intensity and under conditions of high humidity or very light misting but without heavy wetting of the leaves. Most hardwood cuttings, however, do not have leaves. It is necessary to apply a bottom heat temperature of 24 to 26^{0}C for good results. Cuttings can be rooted in sand alone or in a mixture of sand or perlite and peat moss in a ratio of 1:1 (v/v). Dipping cuttings into a fungicide can prevent fungal diseases (Davis, Haissig and Sankhla, 1989).

Hartmann *et al.* (1997) suggested that the type of wood to be used in making the cuttings varies with the particular species being rooted. Stem cuttings of leafy hardwood cuttings are made from 10 to 20-cm-long twigs with all the leaves removed from the lower half. Mature terminal shoots of the previous season's growth are usually used. In some cases older and heavier wood can also be used resulting in a larger plant when it is rooted, as in *Juniperus chinensis*. Some propagators use small tip cuttings that are 5 to 8 cm long and placed very close together in a flat for rooting. Cuttings of *Taxus* root best if they are taken with a piece of old wood at the base of the cutting. These cuttings seem to be less subject to fungal attack. Also some type of basal wounding is beneficial in inducing rooting for certain narrow-leaved evergreen species.

2.2.1.2 Semi-hardwood cuttings

Cuttings of this type are usually made from woody broad-leaved evergreen species. The leafy summer cuttings taken from partially matured wood of deciduous plants could also be considered as semi-hardwood (Hartmann and Kester, 1975). Cuttings of broad-leaved evergreen species are generally taken during the summer from new shoots just after a flush of growth has taken place and the wood is partially matured. A few fruit species, such as olive and citrus can be propagated in this manner. Many ornamental shrubs, such as Euonymus, Camellia, rhododendron, holly and the evergreen azaleas are propagated in this way.

According to Hartmann *et al.* (1997), semi-hardwood stem cuttings are made from 7.5 to 15 cm long shoots with leaves retained at the upper end. Where leaves are large, they should be trimmed to reduce the leaf surface area as that allows closer spacing in the cutting bed and lowers transpirational water loss. The basal cut is usually made just below a node. The shoot terminals are often used in making cuttings.

Cuttings should be made in the cool and early morning hours when leaves and stems are turgid. The cuttings should then be placed in large polyethylene bags to maintain a high humidity. Cuttings should be kept out of the sun until propagation is initiated. It is necessary that leafy cuttings be rooted under conditions that will keep water loss from leaves at a minimum. On a commercial scale, cuttings are ordinarily rooted under intermittent mist sprays or fog. Bottom heat and auxin treatments are also beneficial. Rooting media such as a 1:1 (v/v) mixture of perlite and peat moss, or perlite and vermiculite give satisfactory results (Hartmann *et al.,* 1997).

2.2.1.3 Softwood cuttings

Softwood cuttings are prepared from the soft succulent, new spring growth of deciduous or evergreen species. Softwood cuttings can start many ornamental woody shrubs. Although fruit tree species are not commonly propagated by this way, apple, apricot, peach, cherry and plum can root, particularly under mist (Hartmann and Kester, 1975).

For some difficult-to-root species, softwood cuttings may be the only commercial method to clonally regenerate cultivars. Softwood cuttings generally root easier and quicker than other types but require more attention and sophisticated equipment. They are always made with leaves attached. It is very important to handle cuttings with care to prevent desiccation and that they be rooted under conditions that will avoid excessive water loss from the leaves. It is quite important to maintain the temperature during rooting at 23-27^{0}C at the base and below 21^{0}C at the leaves. If the light is adequate, ambient air temperature of the mist or fog system can rise to 32^{0}C without detrimental effects on rooting (Hartmann *et al.,* 1997).

Softwood cuttings produce roots in two to five weeks and they respond very well to auxin treatment. For the cuttings to root, it is best to take cutting material that has some degree of flexibility, but mature enough to break when sharply bent. In addition, the growth from portions of the plant in full light is the most desirable to use. Some of the best material is the lateral or side branch of the stock plant. It is not desirable to use extremely fast growing, soft and tender shoots that are likely to deteriorate before rooting and older woody stems that are slow to root or may just drop their leaves and not root. Also weak, thin, interior shoots should be avoided as well as vigorous or heavy woody stems (Dubois and de Vries, 1991).

According to Fretz and Read (1979), softwood cuttings are 7.5 to 12.5 cm long with at least two nodes. The basal cut is usually made just below a node. The leaves on the lower portion are removed. Due to problems of high transpiration rate and the fact that leaves occupy considerable space in the propagation bed, large leaves are reduced in size. All flowers or flower buds should be removed. It is important to collect cutting material early in the day, because softwood cuttings stress easily. They should be kept moist, cool and turgid at all times. It is not recommended to lay cutting material or to prepare it in the sun for even a few minutes because this will cause serious damage. It is also undesirable to soak the cutting material in water for prolonged periods to keep them fresh. It is good to keep cuttings in a refrigerator at 4 to 8^{0}C for one to two days. McConnell, Cruz, and Best (1996) found that with the application of intermittent mist in greenhouses and outdoors, propagation of plants by means of softwood cuttings could be easier and faster.

2.2.1.4 Herbaceous cuttings

Herbaceous cuttings are made from succulent, non-woody plants such as geranium, chrysanthemums, carnations and many foliage crops (Hartmann *et al.*, 1997). An excessive amount of foliage on herbaceous cuttings complicates cultural techniques used to root them. Since they are quite succulent, special care must be exercised to prevent wilting (Fretz and Read, 1979). Easily rooted herbaceous cuttings are used to propagate most florists' crops. They are 8 to 15 cm long with leaves retained at the upper end and they are rooted under the same conditions as softwood cuttings. Under proper conditions, rooting tends to be rapid, resulting in high take-off percentages. For herbaceous cuttings, auxin treatment is required to gain uniformity in rooting and for the development of heavier root systems.

The nodal position of herbaceous cuttings as well as types of cuttings (apical versus basal) can influence shoot growth and finished plant quality of rooted liners. For example, with golden pothos (*Epipremnum aureum*), a 3 cm or longer internode section below the node and a fraction of the old aerial root should be retained on cuttings for most rapid axillary shoot development. Basal cuttings of *Hedera helix* and *Schefflera arboricola* develop longer shoots and roots than apical cuttings.

2.2.1.5 Leaf cuttings

In leaf cuttings, the leaf blade alone or leaf blade plus petiole are used in forming a new plant. The adventitious buds, shoots and roots that form at the base of the leaf, develop into the new plant. The original leaf planted does not become a part of the new plant (Hartmann *et al.*, 1997). The long tapering leaves are cut into sections 8 to 10 cm long. These leaf pieces are inserted three-quarters of their length into the rooting medium. After a period of time a new plant forms at the base of the leaf piece, with the original cutting disintegrating (Hartmann *et al.*, 1997).

When developing plants with fleshy leaves, such as *Begonia rex*, the large veins are cut on the undersurface of the mature leaf and are laid flat on the surface of the propagation medium. The leaf is held down in some manner, with the upper surface of the leaf exposed. Under humid conditions, new plants form at the point where each vein was cut. Then the old leaf blade gradually disintegrates. Another method, sometimes used with fibrous rooted begonias, is to cut large, well developed leaves into triangular sections, each containing a piece of a large vein. The thin outer edge of the leaf is discarded. These leaf pieces are then inserted upright in sand or on a peat-perlite medium, with the pointed end down. The new plant will develop from the large vein at the base of the leaf piece (Hartmann and Kester, 1975).

Some leaf cuttings can be made from an entire leaf (leaf blade plus petiole), the leaf blade only or just a portion of the leaf blade. Then the new plant forms at the base of the petiole or midrib of the leaf blade. An example of this is the African violet (*Saintpaulia*), where each cutting consists of a leaf blade and petiole. After some time, cuttings develop adventitious buds, shoots and roots. The new plant formed at the base of the petiole is then potted and finished with or without the original leaf (Evans and Blazich 1999).

An unusual type of leaf cutting can be made where many new plants arise at the margins of the leaf. The leaf itself eventually deteriorates. In this case, the leaf cutting should be rooted under the same conditions of high humidity as those used for softwood and herbaceous cuttings.

Most leaf cuttings root readily, but the limitation is lack of initiation of adventitious bud and shoot development. Hence, cytokinins should be used to induce bud formation.

2.2.1.6 Leaf-bud cuttings

This type of cutting consists of a leaf blade, petiole and a short piece of the stem with the attached axillary bud. This is also called a single-node cutting. These cuttings are of particular value where roots but not shoots are initiated from detached leaves. The axillary bud at the nodal area of the stem provides the new shoot. This occurs in the propagation of rhododendrons (Hartmann *et al.*, 1997). According to Hartmann and Kester (1975) leaf-bud cuttings start a number of plant species such as the black raspberry, lemon, blackberry, camellia and boysenberry, as well as many tropical shrubs and some herbaceous greenhouse plants. Each node can be used as a cutting. Leaf-bud cuttings are best made from material having well-developed buds and healthy, actively growing leaves.

Treatment of the cut surface with auxin stimulates root production. The cuttings are inserted in the rooting medium with the bud 1.3 to 2.5 cm below the surface.

High humidity is essential and bottom heat is desirable for rapid rooting. Sand, or sand and peat moss in a ratio of 1:1 (v/v) are satisfactory rooting media for leaf-bud cuttings.

2.2.2 Factors affecting propagation of leafy stem cuttings

Differences occur among species and cultivars in the rooting ability of cuttings. I t is difficult to predict whether or not cuttings of a certain clone will root easily. Therefore the practices to be discussed in this section can play vital role to determine success or failure in obtaining satisfactory rooting.

2.2.2.1 Selection and maintenance of stock plants

Management of stock plants to maximize rooting begins with selection of cutting material that is easy to root. Maintenance of stock plants in the juvenile or transition phase to maximize rooting and rejuvenation of stock plant material may be important for difficult-to-root species (Hartmann *et al.*, 1997).

The serial propagation of new generations of rooted cuttings helps maintain the easy-to-root characteristics of a cultivar. It is not economically feasible to use cutting propagation with a new cultivar that has less than 50% rooting, irrespective of their form, flower colour, ornamental characteristics or yield.

To improve rooting success and maintain the stock plant in a physiologically juvenile phase some horticultural and forestry practices can be used. For instance, the development of systems for obtaining whole populations of juvenile or transitional stage cuttings is revolutionizing clonal forestry. Growing seedling populations of elite plasm of Monterrey pines, loblolly pine cuttings from this elite material should rather be taken, using hedging and pruning systems, and serial cutting generations to maintain a high rooting potential (Hamann, 1995). This has exciting opportunities for increasing timber yield.

2.2.2.2 Rejuvenation of stock plants

In woody plants that are difficult-to-root, ease of adventitious root formation declines with age of stock plant. Howard and Ridout (1992), suggested that almost always, either stem or root cuttings taken during juvenile growth phase will root much more readily than those taken in the adult growth phase. In apple, pear and live oak cuttings, the ability to form adventitious roots decreases with increasing age of the plants from seed, in other words when the stock plant changes from the juvenile to the adult phase.

Kamaludding, Ahmed and Jashimuddin (1998) found that in some trees, such as oak, spruce and beech, leaf retention late into the autumn occurs on the basal parts of the tree and indicates the part still in the juvenile stage. Therefore cuttings should be taken from this type of wood. Brutsch (1971) indicated that heavy pruning of pecan trees the previous season might be a means of inducing greater shoot vigour. It is very important to apply any treatment that maintains the juvenile growth phase to prevent the decline in rooting potential as the stock plant ages. For example, the hedging or shearing treatments on *Pinus radiata* trees were quite effective in maintaining the rooting potential of cuttings taken from them as the trees aged, compared to non-hedged trees (Hartmann and Kester, 1975). Such benefits in maintaining rooting potential by hedging may possibly be explained by the prevention of normal phase change from the juvenile to the adult form. For example, stock plants for hardwood cuttings of certain fruit tree rootstocks, are maintained as hedges rather than allowed to grow to a tree form.

Hartmann *et al.* (1997) suggested that in rooting cuttings of difficult species it would be useful to be able to induce rejuvenation to the easily rooted juvenile stage from plants in the mature form. This can be achieved by following certain practices. Rejuvenation of apple can be done with mature trees by causing adventitious buds or shoots to develop from root pieces, which are then made into softwood stem cuttings and rooted. Removing terminal and lateral buds, and spraying stock plants with a mixture of cytokinin, tri-iodobenzoic acid and daminozide can force many *Pinus sylvestris* fascicular buds out.

In some plants juvenile wood can be obtained from mature plants by forcing juvenile growth from sphaeroblasts, wartlike protuberances containing meristematic and conductive tissues, sometimes found on trunks or branches. These are induced to develop by disbudding and heavily cutting back stock plants. Using the stooling method on these rooted sphaeroblast cuttings produced rooted shoots that continued to possess juvenile characteristics. Grafting is another method, where grafting mature forms of ivy onto juvenile forms has induced a change of the mature to the juvenile stage.

Waxman (1962), cited by Jull, Warren and Blazich (1994), reported that stem cuttings taken during active growth (softwood) are composed of cells that are actively dividing and elongating, and may contain a high concentration of root-promoting factors (auxin). These cells quickly initiate roots.

2.2.2.3 Type of wood selected

There are many choices to be made in respect of the type of material to use, ranging from softwood terminal shoots of current growth to dormant hardwood cuttings. It is impossible to suggest any one type of cutting material that would be best for all plants, in that what may be ideal for one plant could be a failure for another.

Differences may be between lateral and terminal shoots, where softwood cuttings root better from terminal shoots, and semi-hardwood cuttings root better from lateral shoots. In rooting different types of softwood plum cuttings, there was a marked superiority in rooting of lateral shoots, compared with terminal shoots in spring (Hartmann *et al.,* 1997). Similarly, in rhododendrons, thin cuttings made from lateral shoots consistently give higher rooting percentage as compared to those taken from vigorous, strong terminal shoots. Marked differences exist in the chemical composition of such shoots from the basal portion to the tip. Cuttings made from shoots of three cultivars of the bush blueberry (*Vaccinium corymbosum*) root better if taken from the basal portion than from the terminal portion of a shoot.

Herbaceous dahlia cuttings bearing flower buds are more difficult to root than cuttings having only vegetative buds. The flowering can serve as a competing sink to the detriment of rooting. Therefore, it is economically desirable to remove flower buds from cuttings for more rapid root development (Hartmann and Kester, 1975).

2.2.2.4 Seasonal timing

Time of the year to take cuttings has a dramatic influence on the results obtained in rooting cuttings and may provide the key to highly successful rooting. Most propagators strive to maintain the plant's momentum by rooting during the plant's optimal periods to maximize the rooting process and speed up the production of liners (Curir, Sulis, Bianchini, Marchesis, Guglieri and Dolci, 1992).

Hartmann *et al.* (1997) reported that certain species, such as privets, could be rooted easily if cuttings are taken almost any time of the year. Excellent rooting of leafy olive cuttings under mist can be obtained during late spring or summer but rooting drops almost to zero with similar cuttings taken in mid-winter. The effect of timing is noticed on difficult-to-root deciduous azalea cuttings. These cuttings root easily if the cuttings are taken from succulent growth in early spring, but the rooting percentage declines rapidly if cuttings are taken in late spring. Therefore it is important that trials be conducted to determine the optimum time to take cuttings, which is more related to the physiological condition of the plant than to any given calendar date.

Hardwood cuttings of deciduous species should be taken during the dormant season, from leaf fall, when buds are dormant and before buds start to force out in spring. The effects of timing are merely a reflection of the response of the cuttings to environmental conditions at different times of the year. When hardwood cuttings of deciduous species are taken and planted in the nursery in early spring, after the rest period of the buds has been broken by winter chilling, buds quickly open with the onset of warm days. The new developing leaves will start to transpire and release the moisture from the cuttings before they have the opportunity to form roots, ultimately resulting in the death of the cuttings.

With *Rosa multiflora,* under an intermittent mist system where water was not a limiting factor, new expanding buds and shoots were also competing sinks for metabolites and phytohormones, to the detriment of rooting. Therefore, hardwood cuttings can be taken and planted in autumn while the buds are still in the rest period, so that roots may form and be well established by the time the buds open in the spring (Curir *et al.,* 1992). In rooting narrow-leafed evergreen cuttings it is recommended that cuttings should be taken during the period from late autumn to late winter. In an experiment with Juniper cuttings, their rooting was lowest during the season of active vegetative growth and highest during the dormant period (Hartmann and Kester, 1975).

2.2.2.5 Rooting media

The propagation media for cuttings depend on the species, cutting type, season, cost, propagation systems and availability of the medium components. The purpose of a rooting medium is to satisfy the needs for good cutting growth within the limited space of a container and to prepare it for successful transplanting into a larger container or into the field. The rooting medium functions to hold the cutting in place during the rooting period and to provide moisture for the cutting. It also helps to permit penetration to and exchange of air at the base of the cutting, and to create a dark environment by reducing light penetration to the cutting base Landis, Tinus, McDonald, and Barnett, (1990).

An ideal rooting medium also provides sufficient porosity to allow good aeration, has a high water holding capacity and is well drained (Days and Loveys, 1998). The rooting medium is also slightly acidic with good cation exchange capacity, free of insects, diseases and weed seeds, low in silt, clay and ash content, and easily stored for long periods of time without changes in physical and chemical properties.

Propagation media include a coarse mineral component, which is used to increase porosity. Therefore, porosity is important in growing media because it determines the space available in a container for air (aeration), water and root growth. Aeration is important because the root system breathes (exchanges oxygen and carbon dioxide) in the large, air-filled pores (macropores). If poor aeration occurs it will adversely affect root form and structure, and will lead to decreased cutting vigour (Miller and Jones, 1995). Mineral components include perlite, vermiculite, expanded shale, grit, scoria, polystyrene and rockwool.

Organic components used in growing media have a large proportion of micropores that improve water-holding capacity, a good texture that resists compaction and a relatively high cation exchange capacity (CEC). They include peat, sphagnum moss, softwood and hardwood barks. According to Hartmann *et al.* (1997) most propagators use a combination of organic and mineral components, such as peat-perlite; peat-vermiculite-perlite; peat- rockwool.

The desired pH of most growing media is slightly acidic, ranging from 5.5 to 6.5. Cation Exchange Capacity is a measure of the medium's ability to hold nutrients. A low CEC of 10 meq/100 g will not retain nutrients; they will wash out from the mix during watering. A high CEC (140 meq/100 g) results in nutrients being sufficiently held. Initially, low fertility in a growing medium is desirable in order to minimize fertilizer burning (Miller and Jones, 1995).

It is recommended that integrated pest management (IPM) be applied to rooting media during rooting to control damping-off organisms such as *Phytophthora, Glomerella*, and *Rhizoctonia spp.* Integrated pest management includes the selective use of broad- spectrum fungicides on cuttings (Miller and Jones, 1995).

2.2.3 Treatment of cuttings

Various treatments of stock plants and/or cuttings can enhance rooting, particularly with difficult-to-root material.

2.2.3.1 Wounding

According to Cline and Neely (1983), root production on stem cuttings can be promoted by wounding. Wounding has proved useful in a number of species, such as arborvitae, holly, maple and rhododendron. With narrow-leaved evergreen species such as arborvitae, stripping off the lower branches of the cutting may produce wounds. Stripping basal leaves of cuttings reduces the propagation bench space required for some species and may serve to improve the contact area between the cutting and media.

Fretz and Read (1979) stated that slice wounding before auxin treatment is beneficial when IBA treatment is applied as a powder formulation, but detrimental when a readily absorbed alcoholic solution of IBA is used. In a few cases, wounding can be beneficial, irrespective of auxin treatment.

A vertical cut with the tip of a sharp grafting knife is made down each side of the cutting for 2.5 to 5 cm, with penetration through the bark and into the wood. A more drastic wound is made with a razor blade device which consists of four single edge blades soldered together along the back. The four wound cuts are made simultaneously with this equipment.

According to Garner and Chaudhri (1976) and Hartmann *et al.* (1997), larger cuttings, such as magnolias and rhododendrons, may be more effectively wounded by removing a thin slice of bark for about 2.5 cm from the base on two sides of the cutting. This helps to expose the cambium, without cutting deep in the wood. Wounded tissues are stimulated into cell division and production of root primodia. This happens because of a natural accumulation of auxins and carbohydrates in the wounded area. It also results in an increase in the respiration rate and the creation of a new sink area. Cline and Neely (1983) found that injured tissues from the wound produce ethylene, which may indirectly promote adventitious root formation. Wounded cuttings may also permit greater absorption of applied growth regulators by the tissue at the base of the cuttings.

2.2.3.2 Auxins

The purpose of treating cuttings with auxin type growth regulators is to increase the percentage of cuttings that form roots, and to hasten root initiation. Auxins increase the number and quality of roots produced per cutting and increase uniformity of rooting.

According to Wiesman and Lavee (1995), cuttings for mist propagation are usually taken during spring and summer. In spite of the high morphogenetic potential of the trees, the low rooting ability of difficult-to-root cultivars and often unsatisfactory viability of cuttings of some easy-to-root cultivars are limiting factors. Therefore adventitious root initiation in such cuttings can be stimulated by auxins, particularly indole-3-butyric acid (IBA). Also naphthaleneacetic acid (NAA) may be beneficial in promoting root initiation. IBA and NAA are often used in combination (Verma and Puri, 1996).

IBA is the best auxin for general use because it is non-toxic to plants over a wide concentration range. It has been reported that auxin improves rooting ability and survival in several plant species. Davis and Haissig (1990), as cited by Wiesman and Lavee (1995), reported that while auxin stimulates rooting, cytokinin and gibberelin inhibit it. Therefore, paclobutrazol (PBZ) is used to inhibit gibberelin biosynthesis and urea-phosphate (UP) enhances hormone uptake and activity.

These two compounds (PBZ and UP) interact with IBA and improve rooting and survival of bean and peach cuttings.

Gouws, Jacobs and Strydom (1990) found that the auxin application to the cut base of protea stem cuttings was more effective than to the proximal epidermis when the powder was preceded by an organic solvent as with cuttings dipped directly into the solvent. This method is a concentrated solution dip where a concentrated solution varying from 500 to 10 000 ppm of auxin in aqueous solution or 50% alcohol is prepared. The basal part of cuttings (0.5 to 1 cm) is dipped in it for a short time (5 seconds). The cuttings are then inserted into the rooting medium. With the concentrated solution dip for hardwood cuttings of some species, the propagator can dip just the basal cut surface and this gives better results (Gouws *et al.,* 1990).

Some propagators prefer to spray auxins to the point of run-off to the bases of cuttings or on the foliage before sticking (Hartmann *et al.,* 1997). Cuttings can also be stuck in trays and the auxin solution sprayed on the leaves and stems until beads of liquid drop down into the rooting medium. An excellent rooting of herbaceous cuttings of plumbago, ivy and ficus has occurred with the total immersion of the whole cutting in 50 to 250 ppm IBA for few a seconds.

The dilute solution soaking method is when the basal part (2.5 cm) of the cutting is soaked in a dilute solution of the material for 24 hours, just before they are inserted into the rooting medium. The concentrations used vary from about 20 ppm for easily rooted species to about 200 ppm for more difficult-to-root species. Hartmann *et al* (1997) suggested that by soaking basal portions of hard-to-root cuttings of *Prunus*, conifers, evergreen and deciduous shrubs for a maximum of four hours in 50 to 150 ppm IBA, a greater success might be achieved where the cuttings are propagated under mist.

2.2.3.3 Mineral nutrition of cuttings

Stock plants should be maintained under optimum nutrition before the collection of cuttings. This helps to minimize problems that can lead to death of cuttings. Plants that are in good nutritional state and are growing under good environmental conditions of temperature, moisture and light will have a relatively high C:N ratio in the tissues. Therefore, cuttings collected from plants under those conditions will produce a greater number of roots than those taken form plants having a low C:N ratio. Mineral nutrients added to the water used for misting may improve root quality and subsequent growth of rooted cuttings. Softwood cuttings of plants collected from stock plants growing under poor fertility conditions during the middle of the summer will root more slowly than cuttings taken from plants growing under good soil management practices.

Good management includes regular spray programs for insects and diseases, thereby ensuring a maximum amount of foliage, the provision of ample moisture in the root zone and maintenance of a well-balanced fertilizer program. Plants in these conditions would be quite succulent and capable of rapid regeneration (Fretz and Read 1979). Slow-to-root cuttings held under mist for prolonged periods may have a large amount of their nutrients leached away. Leafy hardwood cuttings are more susceptible than softwood or herbaceous cuttings to the leaching of nutrients. Therefore, it is recommended to apply slow release macro and microelements to the propagation media. This can be done either by pre-incorporation into the media before sticking cuttings or by broadcast during propagation.

The top dressing of Osmocote^R 18-6-12 at the rate of 6.8 to 13.8 g/m^2 enhances both root and shoot growth of *Ligustrum japonicum.* Generally, slow release formulations with a slow initial release rate (12 to 14 months, Osmocote^R 17- 3.1-8.1) are better suited for top dressing on the surface of propagation media under mist systems than short release (3 months) formulation (Hartmann *et al.*, 1997).

After roots have been initiated, dilute liquid fertilizer can be applied to the propagation medium. Plant growth is thus maintained and propagation turnover occurs quickly by producing rooted liners that are nutritionally balanced.

2.2.3.4 Storage of cuttings

It is important sometimes to collect cuttings when nursery plants are pruned and to store them for later propagating. Most nurseries have refrigerated storage facilities at 4 to 8°C for holding cuttings 1 to 2 days or longer before processing for propagation. Cuttings are first misted to reduce transpiration and then refrigerated.

According to Garrido, Cano, Acosta and Sanchez (1998), newly rooted softwood cuttings of selected species can be difficult to over-winter and simply cannot be transplanted to the field from their rooting beds. Therefore storing rooted cuttings in cold storage allows growers to commit valuable greenhouse over-wintering space to the production of other crops. The planting season can also be extended because the rooted cuttings are held in a state of dormancy into the spring. Cuttings should be allowed to partially dry before pulling them from the rooting beds and then put in poly bags packed with materials to act as insulation and to absorb excess water. Rooted softwood cuttings of certain species successfully survived up to 7 months when stored at -2 to 2^0 C. Also, softwood cuttings of azaleas were taken in spring and held for 10 weeks in polyethylene bags at -0.5 to 4.5 ^{0}C with no adverse effect on rooting (Hartmann *et al.*, 1997).

According to Hartmann and Kester (1975), unrooted carnation cuttings could be stored in sealed plastic bags for several weeks at -0.5°C for subsequent rooting. Pre-storage of chrysanthemum for 12 days at 10^0 C enhanced rooting of cuttings compared to non-stored cuttings. Carnation cuttings, either rooted or unrooted, store well at -0.5^{0}C for at least 5 months if placed in polyethylene-lined boxes with a small amount of moist sphagnum or peat moss. Rooting of cuttings while in storage helps producers to store cuttings for a more convenient time to propagate.

2.2.4 Environmental factors

For the successful rooting of leafy stem cuttings, the essential environmental requirements are proper temperature, ample light, and an atmosphere conducive to low water loss from the leaves.

2.2.4.1 Light

Light is very important for plant growth in that it is the source of energy for photosynthesis. In rooting leafy cuttings, the products of photosynthesis are important for root initiation and growth. Light intensity and duration must be great enough so that carbohydrates will accumulate in excess of those used in respiration (Davis and Haissig, 1990).

Hartmann *et al.* (1997) indicated that some cuttings of herbaceous species such as geranium, poinsettia and chrysanthemum rooted better in tests when the irradiance increased to 116 watts per square meter during trials in winter months. Very high irradiance damaged leaves of cuttings, delayed rooting and reduced root growth. There is evidence that the photoperiod under which the stock plants are grown exerts an influence on the rooting of cuttings taken from them. If the photoperiod influences photosynthesis it may be related to carbohydrate accumulation, with the best rooting obtained under photoperiods which promote increased carbohydrates. In some species, the photoperiod under which the cuttings are rooted may affect root initiation. Therefore long days are generally more effective than short days. For example, in propagation by leaf cuttings there must be development of adventitious buds and roots. Lighting that provides more red than far red light appears to increase rooting in many greenhouse crops. Radiation in the orange-red end of the spectrum seems to favour rooting of cuttings more than in the blue region.

2.2.4.2 Temperature

Temperature of the propagation medium can be sub-optimal for rooting due to the cooling effect of mist. It is cost effective and satisfactory to manipulate temperature by heating propagation benches because temperature has a strong effect on cuttings (Brits, 1987; Hartmann *et al.*, 1997).

Optimum temperatures vary with different species. Therefore, the optimum medium temperature for propagation of temperate climate species is 18 to 25^0C and 7^0C higher for warm climate species (Hartmann *et al.,* 1997). The suitable temperatures can be maintained by bottom heat. It is important that the mist maintains an adequate moisture status.

2.2.4.3 Water relations

The loss of water from the leaves may reduce the water content of the cuttings to such a low level as to cause them to die. The water status of cuttings is a balance between transpirational losses and uptake of water. The cutting base and any foliage immersed in the propagation media are main entry points for water. Excess water reduces media aeration and can cause disease problems (Hartmann and Kester, 1975). To counteract the problem of water loss, the technique for rooting leafy cuttings under mist was developed (Newton and Jones, 1993). These sprays maintain a film of water on the leaves. Misting results in both a high relative humidity surrounding the leaf and leaf temperatures. Therefore, under mist, conditions are ideal for rooting leafy cuttings, in that transpiration is reduced to a low level. The light intensity can be high, thus promoting full photosynthetic activity. The temperature of the entire cutting is relatively low, thereby reducing the respiration rate (Loach, 1988).

2.2.5 Care of cuttings

Rooted cuttings require special care to ensure successful propagation.

2.2.5.1 Drainage

Uneven moisture distribution during rooting is the most common cause of cutting death. The propagating medium should never be allowed to dry out. Good aeration is needed. Adequate drainage must be provided so that excess water can escape and avoid causing the rooting medium to become soggy and waterlogged. When peat or sphagnum moss is used as a component of the rooting medium, it is important to see that it does not become excessively wet (Hartmann *et al.*, 1997). Media may have a higher water holding capacity than desired for rooting. This could lead to problems with bacterial soft rot, fungus gnats or slow rooting if the medium becomes water logged.

2.2.5.2 Weed control

Weeds can be a serious problem during propagation of woody nursery crops. Therefore weeds should be removed to prevent seeding and competition with cuttings. To control weeds during propagation, the medium must be weed-free, pasteurized or gas-sterilized. It is quite important to keep the perimeters adjacent to the propagation area free of weeds (Hartmann *et al.*, 1997).

2.2.5.3 Hardening-off

This is the process of acclimating rooted cuttings from the high humidity of mist or fog to reduced humidity. This helps cuttings to be self-sufficient in absorbing nutrients and water through the root system. Hardening-off helps new developing leaves and stems to tolerate lower relative humidity, high temperature and more light (Hartmann and Kester, 1975). Cuttings tend to deteriorate when left under mist too long after they have rooted. This deterioration reduces root quality, causes premature leaf drop and slows down the plant's momentum. Therefore hardening-off encourages better root development from rooted cuttings.

The hardening-off is performed in several ways. This can be achieved by leaving the cuttings in the mist bed with the amount of the misting gradually could decreased by lessening the ON periods, by increasing the OFF periods, or by a combination of both.

Some propagators pot the cuttings immediately after rooting and hold them for a time in a cool, humid, shaded location. Another method is to root cuttings in flats and move the flats after rooting to a lathhouse or cold frames, and then pot into containers as rooted liners. Cuttings may be left in the rooting medium until the dormant season, when they can be dug more safely, to be lined out in the nursery for further growth (Garner and Chaudhri, 1976). Well hardened cuttings, rooted as "plugs" in cavity trays, can be transplanted directly in the field.

2.2.5.4 Mist propagation

The main aim of the intermittent mist propagation is to maintain a film of water on the leaf surface at all times which results in a reduction of leaf temperature and leads to reduced transpiration and respiration. Intermittent mist controls water loss from cuttings by reducing both leaf and surrounding air temperature via evaporative cooling and the raising of relative humidity. This makes possible propagation under high light intensity with accompanying high rates of photosynthesis (Loach, 1988).

McConnell, Cruz and Best (1996) stated some advantages of intermittent mist propagation as follows:

- There is little loss of food material from the cuttings by leaching.
- Nutrients provided in the medium remain there, for use as soon as roots form.
- The rooting medium is not subjected to much lowering of its temperature through excessive water.
- Moisture content of medium is controlled within predetermined limits, instead of being virtually at field capacity the whole time.

It is advisable to maintain a certain temperature at the base of the cuttings to secure rooting at the base of cuttings before shoot growth starts. Providing bottom heat from thermostatically controlled heating cables or hot water pipes under the rooting frames best does this. The bottom heat is frequently used to counteract the problem of lower media temperatures caused by mist. The bottom heat is used in outdoor and indoor rooting structures (Rana, 1996).

An intermittent mist enables the rooting of cuttings of plants previously considered very difficult or impossible to root. This permits the use of soft, succulent, fast-growing cutting material early in the season, which in some species is much more likely to root than older, more mature, hardened wood. It also keeps slow rooting cuttings alive for a long period of time, giving them a chance to root before they die from desiccation. By the use of mist propagation techniques, large cuttings with considerable leaf area can be rooted, permitting the production of large-sized, salable plants in a short time (Newton and Jones, 1993).

Hartmann and Kester (1975) indicated that while the primary benefit in rooting under mist is in controlling water loss, a secondary benefit could be in sufficiently changing the physiological conditions of the tissues to promote an increase in rooting. They found that Euonymus plants grown under mist accumulate natural root-inducing phenolic and flavenoid compounds so that cuttings taken from them rooted much more readily than did those from non-misted plants.

Intermittent mist is of two types, the enclosed mist bed and open mist bed. An enclosed mist utilizes polyethylene-covered structures in a glasshouse that reduce the fluctuation in ambient humidity common to open bench mist. It also ensures more uniform wetting of foliage, since air currents are reduced. This system is effective in propagating difficult-to-root species, softwood cuttings of large-leaved species (*Corylus maxima*) and broad-leaved evergreens. With the enclosed mist system, disease problems are lower than with the open mist system, because there is less mist required, less media saturation and fewer leaching problems (Newton and Jones, 1993). Hartmann *et al.* (1997) indicated that open mist systems are used in outdoor propagation in cold frames, polythylene tunnels, and shade houses and under full sun. It is also used in glass and polycarbonate-covered greenhouses and set up on the floor area or above the propagation bench. For this system, a very short duration (3 to 15 seconds) should be used for misting. Besides using fixed risers with mist nozzles, mechanized traveling boom systems are used to deliver mist to cuttings.

2.2.6 Handling of cuttings after rooting

After the cuttings have produced a root system 2,5 to 7,5cm long, they are transplanted from the bed or flat into a potting mixture. The time required to form an adequate root system depends upon the kind of plant and type of cutting. Most shrubs will root within three to six weeks. Leaving young plants in the rooting medium after rooting with little additional care will stunt them. If rooted plants cannot be stepped up (potted or moved to a new bed) soon after rooting, a water-soluble fertilizer is applied at half the recommended rate. Watering with this fertilizer solution is done every other week (Wade and Garber, 1994).

Rooted hardwood cuttings in the nursery row are dug during the dormant season after the leaves have dropped. With the fast-growing species, the cuttings may be sufficiently large to dig after one season's growth. The slower growing species may require two or three years to become large enough to transplant.

The digging in nursery rows should take place on cool and cloudy days, when there is no wind. It is advisable that the digging should not be done when the soil is wet, particularly if it has high clay content. If only a few plants are to be removed from the nursery row, they can be dug with shovels or spades. In large-scale nursery operations some type of mechanical digger is used. This digger undercuts the plants. A sharp U- shaped blade travels 30 to 60 cm below the soil surface under the nursery row, cutting through the roots. Sometimes a horizontal, vibrating, lifting blade is attached and travels behind the cutting blade. This blade lifts the plants out of the soil and shakes the soil from the root system, making them easy to pull by hand (Hartmann *et al.*, 1997)

After the plants are dug, they should be quickly heeled-in in a convenient location, placed in cold storage or replanted immediately in their permanent location. Heeling-in is placing dug, bare-rooted deciduous nursery plants close together in trenches with the roots well covered. This is a temporary provision for holding the young plants until they can be set out in their permanent location. Healing-in outdoors in a well-drained site is an adequate method of over-wintering autumn-harvested plants, especially when the winter is mild and the plants will be shipped in early spring.

Garrido *et al.* (1998) mentioned that nursery stock to be kept for extended periods should be held in cold storage, ideally with jacketed cooler systems, with relatively high humidity (+/- 95%) and temperature of 0 to 2 ^{0}C. Wooden boxes filled with moist sawdust or barks are used to hold larger plants and seedlings until they can be field planted in the spring. Rooted cuttings are very susceptible to cold injury. Therefore, they are grown in a cold frame for the first season. Cuttings rooted in the early summer are transplanted to an open cold frame. In the autumn, this cold frame is covered with sash or plastic sheeting. Cuttings rooted in late summer or autumn can be transplanted immediately from the propagating medium to a closed cold frame. Propagation flats can be placed directly inside the cold frame. Cuttings in flats are then transplanted in the spring. The cold frames need not be elaborate. The sides can be constructed of cement blocks or scrap lumber. The cover can be polyethylene plastic over a wooden frame.

The cuttings of herbaceous, semi-hardwood, leaf-bud, softwood and leaf cuttings are rooted with leaves attached and under conditions of high humidity. They require considerable care in being removed from the rooting medium. Ventilation should be provided and the humidity lowered after rooting has started. The cuttings should be dug after the first-formed primary roots have branched to develop a dense, fibrous secondary root system to which the rooting medium clings in a ball (Hartmann and Kester, 1975).

In digging, the cuttings should be lifted gently from the rooting medium with a trowel, taking care not to break off the roots. If peat moss or vermiculite is the rooting medium, it is desirable for the cuttings to be lifted out with a mass of the rooting medium still adhering to the roots (Garrido *et al.*, 1998).

3. AGRO-ECOLOGY OF THE AREA AND INFRUSTRUCTURE

In this section we look at pertinent aspects of the agro-ecology and infrastructure of the study area.

3.1 Geographical situation

The Melani village is about 7 km North of Alice and about 25 km South of Hogsback. It is one of several villages close to the town of Alice town and in Nkonkobe District.

3.2 Climate

In order to establish *A. afra* it is important to consider the climate of the area.

3.2.1 Rainfall

Rainfall is a major climatic factor determining agricultural potential and production practices. Acocks (1975), as cited by Dube (1997), stated that Victoria East is characterized by relatively wet summers and dry winters where February and March are the wettest months, while June and July are the driest months. Due to insufficient or irregular rainfall in summer, rainfed cropping is greatly hampered in the (former) Ciskei region of the Eastern Cape, so that careful adjustments of planting dates are vital on rainfed crops to avoid a co-incidence of critical growth stage with dry spells. The potential evapo-transpiration exceeds the rainfall in all the months. The annual rainfall ranges from 400-650 mm.

3.2.2 Temperature

The average daily maximum is around 29.5°C in January and 20.6°C in July. The mean summer temperature ranges from 18-21°C and mean winter temperature from 10-13°C. Therefore these temperatures indicate a relatively moderate climate. Dube (1997) indicated that the Ehler's code is 77/35, based on agro-ecological maps and calculations from the Lovedale data.

3.2.3 Wind

In the Eastern Cape winds blow mostly parallel to the coast namely north-easterly and south-westerly. During north-easterly winds, the sky is usually cloudless and hazy. South-westerly winds bring cool, cloudy wheather and rain. Sometimes, mainly during the late winter and during summer, very dry and hot berg winds are experienced.

3.3 Soils

Shallow, young soils, generally on shale or sandstone predominate in the Greater Ciskei, including where Melani, village is situated. The main soil forms present are Glenrosa, Westleigh and Hutton. Marais, Brutsch, Laker and Graven (1975) reported that a large proportion of the Tyumie area is arable.

3.4 Infrastructure

Infrastructure can have an important influence on an essential oil industry.

4.4.1 Roads

Transportation infrastructure is one of the major factors which determine the development of an area. The Melani village is along the tar road from Alice to Hogsback. There is a gravel road to the village. The condition of the roads in Melani village is bad.

3.4.2 Water

About 46% of the farmers with plots on the small irrigation scheme get water from the Tyume River to irrigate their crops. There is a water pipeline from Binfield Dam to Alice which runs through the village. Water taps are very few and only those people who are close to the taps can use them as a source of irrigation water for their back gardens and for domestic usage. Some people get water for irrigation from the rain that they collect and store in tanks.

3.4.3 Fencing

Fencing helps to reduce theft and also the damage which can be caused by the livestock to cultivated land. The cropping fields and many yards at Melani are fenced.

4. METHODOLOGY FOR SURVEY

The section that follows highlights certain aspects of the survey in terms of the study area, the questionnaire, sampling and interviewing, and data analysis.

4.1 Choice of the study area

According to Sprodley (1980) there are factors that can be identified in the selection of the research site for a survey. These factors include:

- The research site must allow researchers to move from studying simple situations to those which are complex.
- Accessibility, that is the degree of access and entry that is given to the researcher.
- Lack of impediments, that is the situation that allows the researcher to take an unhindered role.
- Acceptability, that is the situation that allows the researcher free or limited or restricted entry.

The Melani village in Alice was selected as a suitable area in which this study could be undertaken in that there is a farmer who is extracting oil from selected essential oil crops close to the village. This farmer was also growing African wormwood under irrigation for commercial purposes.

4.2 Questionnaire objective and design

Both open-ended and closed questions were designed and compiled in order to determine the respondent's knowledge about domestication and propagation of African wormwood. Questionnaires were also designed to investigate infrastructure, labour availability and communication channels used by the households in Melani village.

According to Huysamen (1994), a self-administered questionnaire has the advantage of flexibility, thus enabling the researcher to ensure that the respondent understands the questions and the purpose of the study. It also permits the interviewer to probe further when a particular response is encountered, as well as allowing subjective assessment and rating to be made of attitudes, opinions and knowledge.

4.3 Sampling procedure

According to Bless and Smith (1995) a sample is the subset of the whole population which is actually investigated by a researcher and whose characteristics will be generalized to the entire population. Sampling is said to be the only practicable method of data collection, in particular when the population is extremely large. To gather data on a sample is less time consuming and is less costly since the costs of research are proportional to the number of hours spent on data collection.

4.4 Sample size

The respondents were selected randomly as randomization expresses the idea of chance being the only criterion for selection. The selection of an element from the population is called random when each element of the population has the same chance or probability of being chosen for the sample (Bless and Smith, 1995). A simple random sample of 80 households was taken at Melani village in Alice.

4.5 Interviewing procedure

Bless and Smith (1995) indicated that an interview involves direct personal contact with the participant who is asked to answer questions. Therefore, the researcher gets information directly from respondents by means of a scheduled structured interview. This method is based on an established questionnaire which has a set of questions with fixed wording and sequence of presentation.

The researcher met the chairman of the Melani village after that chairman arranged a meeting where the researcher explained what the research was all about and the relevance of it to the community members and farmers. The farmers and community members were visited in their homes and working fields. The right to use any language and the level of education were taken into cognizance in the expression of the questionnaire. The questionnaires were typed in English, but the people of the study area were Xhosa speaking. The interviewer, however, being bilingual, conducted the interviews in Xhosa.

4.6 Method of Data Analysis

The questionnaires were checked and coded by hand, punched into a Microsoft Excel Spreadsheet and then analysed using the Statistica computer programme to obtain a frequency distribution. This was done to assess the characteristics of the farmers and community members in the study area.

5. CHARACTERISTICS OF THE POPULATION OF MELANI VILLAGE

5.1 Introduction

The survey was developed in the form of a questionnaire for the rural communities and farmers to determine how people feel about the domestication of *Artemisia afra*. The survey, through interviews, assessed their knowledge of the research crop, labour availability and sources of information for the rural communities and farmers. The subjective assessment of the felt needs, institutional factors, sociological and socio-psychological characteristics were also investigated by means of the questionnaire.

5.2 Personal characteristics

5.2.1 Marital status

The marital status of the farmer has some influence on agricultural activity (Spring, 1985). Households headed by married women had an advantage of access to bigger land holdings, location of farm and greater size of the household labour pool. A large proportion of widows depends on neighbours, friends or male members of their extended families for assistance in agricultural production. Steyn (1988) indicated that from the extension point of view it is most unlikely that widows could be motivated to participate in adult education programmes related to the adoption of improved agricultural practices and rural development.

Table 5.1: Distribution of the respondents according to marital status in Melani village, 2000 (n =80)

Marital status	Number	%
Married	46	57.5
Single	18	22.5
Divorced	5	6.25
Widow/er	11	13.75
Total	80	100

The respondents of the study area were mostly married. This is shown in Table 5.1 where they are in the majority (57%). The fact that the majority of the households are married suggests that the population in the study area is sociologically stable. The incidence of divorce was found to be low in the study area where it was only 6%. Widows/widowers constitute 13.75% of the population.

The high percentage (57.5%) of married families suggests that labour is not that much of a problem because the families are stable. Therefore this can have an impact on the ease of accepting new innovations.

5.2.2 Household size

Large families tend to put a lot of stress on the head of the household to provide for all their needs and in order to cope with the most basic needs, important aspects such as the education of the children often suffer first (De Beer, 2000). On the other hand, family size and composition determines the amount of labour which is available.

Table 5.2 Distribution of respondents according to Gender in Melani Village, 2000 (n= 80).

Gender	Number	%
Male	31	39
Female	49	61
Total	80	100

There are more females (61%) than males (39%) in the study area (Table 5.2). This is because many males are working in towns and cities due to the high unemployment rate in rural areas.

5.2.3 Education level

Education is regarded as a basic human need, which in turn is seen as a means of meeting other basic needs and accelerating development through training workers. It plays a vital role in agriculture, in that farmers who are literate get more information in the form of magazines and newsletters, (for example, Farmers Weekly) and often in other languages (English in particular as a medium of instruction in our country). The literate farmers are less inclined to resist changes as far as new innovations are concerned.

Arnon (1981) summarized the effects of education on agricultural production as follows:

- Education provides farmers with the basic skills (reading, writing, arithmetic) which facilitate the transformation of technical knowledge and make possible the keeping of farm records.
- It increases inquisitiveness and thereby improves receptivity for new ideas, opportunity and methods.
- It changes values and aspirations, thereby strengthening the will to recognize and facilitate the adoption of new techniques.
- It makes it easier to overcome traditional, social and cultural constraints, which are barriers to change and progress.

Education level, according to the number of years at school, is shown in Table 5.3. Bembridge (1987) mentioned that according to educationists, people with less than four years of education are unlikely to have attained any degree of literacy. As many as 17.5 % of respondents were people who never attended any school. The people with 1 to 5 years at school are 15%. The elders mostly constituted the level of high illiteracy. The majority of the respondents (37,5%) with 12 and more years at school were young people.

Table 5.3: Distribution of respondents according to school level education, Melani Village, 2000 (n= 80).

Years at school	Number	%
0	14	17.5
1-5	12	15
6-11	24	30
12 and over	30	37.5
Total	80	100

The close proximity of the University of Fort Hare and Lovedale Community College, as well as Phandulwazi Agricultural High School can and does benefit the community.

5.2.4 Health conditions

To assist in meeting the nutritional needs of the rural communities, it is important that small gardens near homes be initiated (Bembridge, Steyn and Tuswa, 1982; Brutsch, 1984; Williams, 1986). These small gardens can contribute to a more balanced diet in the rural areas. From the survey, it appears that the condition of health for many people is good. The Melani village is about 7 km from the Victoria Hospital in Alice.

5.3 Socio-economic factors

5.3.1 Transport

Sokhela, (1990) citing Bembridge *et al.* (1982), stated that forms of transport are a direct reflection of the peoples' mobility and living standard. Apparently the local people have a transport problem for their agricultural products. This is because the type of transport available is public transport, which cannot transport their produce to the market places. A few farmers hire trucks to transport their produce to the local markets. On the other hand, transport for people going to

Alice is not that much of a problem as they use regular taxis. Only a few individuals have their own vehicles.

5.3.2 Occupational status and Labour

Forty two percent of the respondents indicated that they have sufficient labour for their farming activities, through the help from relatives. Their children offer assistance for weeding, irrigation and harvesting, especially during holidays. Fifty eight percent indicated that they do not have sufficient labour due to migration of men from the village to the cities. Approximately 58% of the respondents in Melani village were unemployed, of whom 48.75% were pensioners and 5% students who had passed grade 12 (std 10) but did not access the higher education. Of the respondents 21.25% were self-employed, most of them as farmers (Table 5.4).

The relative lack of job opportunities in the Alice area forces many people to commute elsewhere or become migrant labourers. Low levels of agricultural production and underdevelopment of rural areas are the major causes of migration. According to Mayer and Mayer (1979) migrant labour is the only solution for the rural people to earn a reasonable income. It has been going on for such a long time that it has reached the stage where it is expected of a young man to go to work elsewhere. But the system of migratory labour has negative effects including the disintegration of families, illegitimacy and juvenile delinquency (Hobart-Houghton and Walton, 1952).

Table 5.4: Distribution of respondents according to occupational status, Melani Village, 2000 (n=80)

Occupation	Number	%
Self-employed	17	21.25
Employed, away	14	17.5
Commuter, daily	6	7.5
Student	4	5
Pensioners/Unemployed	39	48
Total	80	100

This suggests that Melani village has no problem of labour because many people are unemployed. Labour availability is important in rural development. Also they may solve their problems by working long hours, employ people and ask help from relatives or neighbours.

5.3.3 Land tenure system

According to Arnon (1981) the prevailing land tenure system in many developing countries is one of the main obstacles towards agricultural development. More than one type of tenure was found in the study area. In a communal system members of a village share in certain land rights. These land rights include access to residential and arable places, collection of firewood, thatching grass and grazing. The government technically owns the land under this system, although the right of land allocation is vested in the headman (de Wet, 1998). In the study area people have a sense of neighbourliness and form a closely kind community. According to the freehold system, ownership of the land rests entirely with the owner who has a title deed registered at the deeds office (Williams, 1986). Some people in the study area own the land according to the freehold system.

5.4 Socio-Psychological factors

5.4.1 Needs

Needs-based development is an accepted departure in the methodologies of extension, where behaviour is directly focused on the goal as a means of need satisfaction (De Beer, 2000). Basic human needs are not concerned with minimum material needs alone. Emphasis is on the social determination of needs, as initial targets are approached new ones will succeed them, and in this sense it is process orientated. It involves participation as a means of achieving those needs as well as a need in itself.

The needs are either individual or community needs. In terms of individual needs, the survey responses showed that respondents really need land, finance to maintain their farming, to cater for household needs and to finance the education of their children. For the community respondent needs indicated job availability, clean water, road construction, markets for their produce and regular visits by a trained extension worker.

5.4.2 Perception and attitudes

Perception is the interpretation or meaning of a situation from the point of view of an individual and is based on his/ her past experience. From the standpoint of agricultural extension it is clear that if a farmer has a different perception from that of an extension worker, the latter will have difficulty in helping him solve his problems and change will be impeded. It relates to prominence compatibility and relative advantage of a proposed innovation as perceived by the (farmer) recipient (De Beer, 2000). Seobi (1980) stated that the people's attitudes could be determined by obtaining their opinions on matters under consideration since opinions are the verbal expressions of attitudes.

The people in the study area know that African wormwood is helpful for their health. They indicated that finance, labour, land and knowledge about propagation of African wormwood are problems they could encounter with production and domestication of African wormwood. They mentioned clearly that their traditions and culture would not prohibit the domestication of African wormwood.

They indicated that production of essential oils could be beneficial to their community in that people will develop technical know-how of essential oil plants. There is a nearby citrus grower who runs an essential oil enterprise. It is not necessary for people to have a still. It can also uplift the standard of living by lowering the unemployment rate. They mentioned that the development they would like to see first in order to start an essential oil enterprise is road construction, land availability and credit availability.

5.4.3 Institutional support

The institutions, the respondents think can help them to start essential oil production in their area, are government, non-governmental organizations and the University of Fort Hare. The help may involve improving the availability of credit and transference of knowledge to the people about essential oil plants.

5.4.4 Information sources

The measures taken to examine the extent to which the farmers are exposed to prevailing information sources were to explore existing communication channels and the extent of effectiveness in promoting the adoption process.

5.4.4.1 Magazines/ Newspapers

Only 20 % of the respondents indicated that they get information from magazines or newspapers. Eighty percent do not read any magazines or newspapers. Forty one percent from this 80% indicated that they can read but also that magazines or newspapers are not readily available, while 28% indicated that they cannot read due to eyesight problems and 11% are illiterate.

5.4.4.2 Farmers' Days

During the interview respondents indicated that the farmers' days they usually attend are those organized by the University of Fort Hare Research Farm. They had never organized their own.

Thirty two percent indicated that they have attended them, while 45% had never attended any and 16% were not aware of Farmers' Days. Fifty percent of those who have attended farmer's days said that they found them interesting and they learned much, while 28% said that it was interesting and they learned something. All those who attended farmer's days before expressed the interest of attending them again because they benefited from them. Also, those who never attended are very interested to attend them in the future.

5.4.4.3 Radio programmes

Radio is useful in creating awareness with older people especially if they do not have TV sets. Radio broadcasts allow information to be spread rapidly among the population (Bolliger, Reichard and Zellwegr, 1994). Almost all the people in the study area are Xhosa speaking people and they listen to Umhlobo Wenene Radio Station. Thirty eight percent of the respondents listen to agricultural programmes. Sixty two percent do not listen to agricultural programmes because the programmes are broadcasted early in the morning whilst people are still sleeping.

5.4.4.4 Extension workers

The respondents mentioned that it is very rare to see an extension worker visiting their village. There is an extension office in the town of Alice, but they are operating without any predetermined programmes. The respondents are of the opinion that the extension workers only visit their area if called for a specific problem and even then they do not have solutions for their problems.

5.4.4.5 Farmers

Seventeen percent of the respondents indicated that they get agricultural information from other farmers. They mentioned that they sometimes get incorrect information from their relatives or neighbours.

6. DOMESTICATION OF *ARTEMISIA AFRA* (AFRICAN WORMWOOD)

Prior to domestication and propagation of any plant, knowledge is required of the micro-environment, the land, and water resources, natural flora and fauna, and local agricultural skills and problems. These include agro-ecological conditions.

Eighty two percent of the respondents, most of them old people, indicated that *A. afra* could be found in the veld, while 18 % indicated that it cannot be found in the veld. Forty one percent of respondents had not seriously considered it for domestication, either because they are not particularly interested in the plant or because they do not have land on which to grow it.

Almost all the respondents indicated that there are no factors which prohibit the domestication of this plant because it is helpful for their health.

6.1 Use of *Artemisia afra*

Artemisia afra is one of the most widely used Southern African medicinal plants.

Almost all the people in the research area use this plant as a medicinal plant. They use it to cure fever, coughs, headaches and colds. They usually boil leaves and drink the solution. If one has only mild fever or headache, leaves are put inside the nose or placed under the pillow. For these reasons they do not regard it as a weed.

6.2 Propagation of *Artemisia afra*

A. afra can be propagated by seeds, cuttings or by digging out the whole plant. People in the research area had not tried to grow this plant by seeds or cuttings and mostly grow it by digging out the whole plant. Only three percent have tried to use seeds, while 39% never tried to grow this plant. No one has tried to propagate this plant vegetatively. They had not noticed any increase in the number of the cultivated plants over the years.

The respondents indicated that they do not know its growth habits because this had not concerned them.

6.3 Growing season

During the interviews, 61% of the respondents mentioned that the suitable growing season for *A. afra* wormwood is spring and summer. They indicated that this plant attains very good green colour during rainy seasons.

6.4 Harvest season

The respondents harvest the leaves of the plant at any time of the year because the leaves are always green and one can use them anytime. To harvest they mostly use their hands and sometimes also scissors or knives.

6.5 Awareness about oil from this plant

All the respondents were not aware of the oil which can be distilled from *A. afra.* They are eager to know how to extract oil from *A. afra.*

It is possible for the rural people to know how to extract oil from the plant because there is a nearby citrus grower who runs an essential oil enterprise. It is not necessary for people to have a still. Other information about distillation of oil can be obtained from the University of Fort Hare Research Farm (M.O. Brutsch, personal communication).

7. THE PROPAGATION OF *ARTEMISIA AFRA* FROM LEAFY STEM CUTTINGS

7.1 Experiment 1. Effect of IBA treatments and rooting media on the rooting of stem cuttings

7.1.1 Introduction

Different Indole Butyric Acid (IBA) concentrations and formulations can be used to enhance rooting of cuttings. Talc powder formulations, in three different concentrations of IBA, for softwood cuttings, semi-hardwood cuttings and for hardwood cuttings, are freely available and easy to apply.

Rooting media can influence rooting and the nature of the root system. There are also considerations of cost and ease of use, in this case using cavity trays. Different media differ in their physical properties, and they influence aeration and moisture retention and therefore also rooting. The objective of this experiment was the testing of different Indole Butyric Acid (IBA) treatments and different rooting media on *A. afra* cuttings.

7.1.2 Materials and Methods

Leafy cuttings of *A. afra* were rooted under intermittent mist in a greenhouse at the University of Fort Hare (UFH) Research Farm. Misting intervals were regulated by a time clock set to deliver a fine mist for 10 seconds every 7.5 minutes during daylight hours. Bottom heat of approximately 20°C was provided.

Cuttings were rooted in three different growing media: palm peat, sand (pool filter sand of 0.8 to 1.4 microns), and a mixture of the palm peat and sand in a 1:1 (v/v) ratio. Standard polystyrene trays, with 128 cavities were placed under the mist and resting on a sand base until roots emerged through the hole at the bottom of the cavity. Trays were then raised (supported on bricks) to ensure that roots did not grow into the sand of the mist bed.

Cavity trays were considered suitable to root *A. afra* cuttings and are particularly convenient for testing different media. A major advantage of "plugs" is that the root system remains intact when the rooted cutting is pulled out of the cavity (provided the medium is suitable and adheres to the roots).

In order to ensure a good healthy supply of cutting material, established *A. afra* plants in the land on the Research Farm had been pruned back hard in spring. Cuttings about 15 cm long were made from somewhat hardened new growth on 16 November 2000. A clean cut was made just below a node and the leaves removed (rubbed off) from the lower third of each cutting (Plate 7.1.1). Every effort was made not to stress the cuttings. They were not left in the sun. As soon as they had been made, they were treated with a commercial preparation of rooting powder, the base of each cutting being dipped into the powder and excess powder tapped off, and then placed in the mist bed.

Two levels of IBA were tested, represented by Seradix® No.1 (active ingredient: indole butyric acid 1 g/kg) and Seradix® No.2 (indole butyric acid 3 g/kg). Seradix® No.1 is a hormone powder for the stimulation of rapid and prolific rooting of softwood plant cuttings. Seradix No.2 is for semi-hardwood cuttings.

The trial was laid out as a randomised complete block design (RCBD) with six treatments and three replications (6 × 3). Each replication consisted of one half of a cavity tray with cuttings of which the perimeter cuttings were considered to be the guard rows and therefore not for sampling. After one month, on 14 December 2000, 20 cuttings for each replicate were examined for rooting. The ease and success of pulling out of the plugs was noted. Rooting media were carefully washed away to leave the root system as intact as possible. Rooting was expressed in terms of the root dry mass and not number and length of roots, because it would have been difficult to disentangle the much branched root system to count and measure roots.

After 2 months, on 12 January 2001, 30 rooted cuttings per treatment were removed (20 in the case of sand) from the remaining undisturbed cavities to obtain an indication of the ease of pulling of the rooted cuttings or “plugs” in the different media after gentle loosening from below (through the hole at the apex of the cavity). Pulling ability refers to the ease with which the plugs could be pulled and remain intact. Pulling success was rated in terms of the root plug (root system plus rooting medium) being “intact”, “partially intact” or “badly broken”. This was a visual, subjective rating and the data was not analysed statistically.
It was expected that after this additional period of 4 weeks the root system in each cavity would have developed further to bind the rooting medium.

Data was analysed as randomised complete block design (RCBD) using MSTAT-C program. Means were separated using the LSD test.

7.1.3 Results

Roots started to appear through the holes at the bottom of the cavity after three weeks. Root development after 4 weeks is shown in plates 7.1.2 and 7.1.3. Twenty cuttings of each replicate were examined for rooting. After four weeks in the mist bed there was no significant difference in terms of rooting between cuttings in palm peat and those in the mixture of palm peat and sand (1:1 by volume). See Table 7.1 and Appendix C. All media with palm peat as the only component, or as a major component, resulted in better rooting than with sand alone and Seradix® no.1. The palm peat and Seradix® no.1 treatments were superior to any of the sand and Seradix® treatments. Sand resulted in poor root development (Plate 7.1.5). There was no significant difference between Seradix® No.1 and Seradix® No.2 in terms of root mass per cutting. See Table 7.1 and Appendix C.

It is evident from Table 7.2 that the rooted cuttings in the sand alone pulled with great difficulty and with considerable damage to the root system. The sand tended to be compacted and also did not form a root plug, as the roots could not adequately bind it. Plate's 7.1.4, 7.1.6, 7.1.7, 7.1.8 and 7.1.9 illustrate the differences in pulling of rooted cuttings.

7.1.4 Discussion and conclusions

Leafy cuttings of *A. afra* root with relative ease and whether Seradix® (IBA) No.1 or No.2 is used is not important. It is evident though that for rooting cuttings in cavity trays the sand tested was not very suitable because it was difficult to remove the rooted cuttings as an intact plug as the roots and medium do not bind together to form a plug. Roots tended to break when trying to pull out the plug. Sand loses water easily due to the larger pores and therefore also dries quickly and this may explain the poor root development. Palm peat alone or in a mixture with sand is a suitable rooting media for *A. afra* cuttings.

As there were no significant differences in rooting mass or pulling success of plugs with palm peat and those with palm peat plus sand, the cheaper or more readily available medium should be used. The sand and palm peat mixture will be cheaper than the palm peat alone. We are not aware of any reported trials with the rooting of *A. afra* cuttings although cuttings have been rooted under mist for some time at the University of Fort Hare.

Table 7.1 Rooting of *A. afra* cuttings treated with IBA and rooted in different media in cavity trays, after one month .

Treatments	Mean Root dry mass (mg)
Sand + Seradix® no.1	26.30c
Sand + Seradix® no.2	32.58bc
Sand plus Palm Peat +Seradix® no.1	41.33ab
Sand plus Palm Peat +Seradix® no. 2	42.09ab
Palm Peat + Seradix® no.1	46.22a
Palm Peat + Seradix® no.2	42.33ab
LSD 0.05	11.11
CV %	15.79%

Means followed by the same letter do not differ significantly from each other ($P \leq 0.05$)

Table 7.2 Pulling successes of rooted *Artemisia afra* cuttings after two months `growing in different media in 128 cavity Styrofoam planter flats.

Treatments	No. Pulled	No. Intact	% Intact	No. Partially Intact	% Partially Intact	No. Broken	%Broken
Sand + Seradix® no.1	20	0	0	11	55	9	45
Sand + Seradix® no.2	20	1	5	10	50	9	45
Sand plus Palm peat + Seradix® no.1	30	22	73	6	20	2	7
Sand plus palm peat + Seradix® no.2	30	24	80	3	10	3	10
Palm peat + Seradix® no.1	30	22	73	5	17	3	10
Palm peat + Seradix® no.2	30	28	93	0	0	2	7

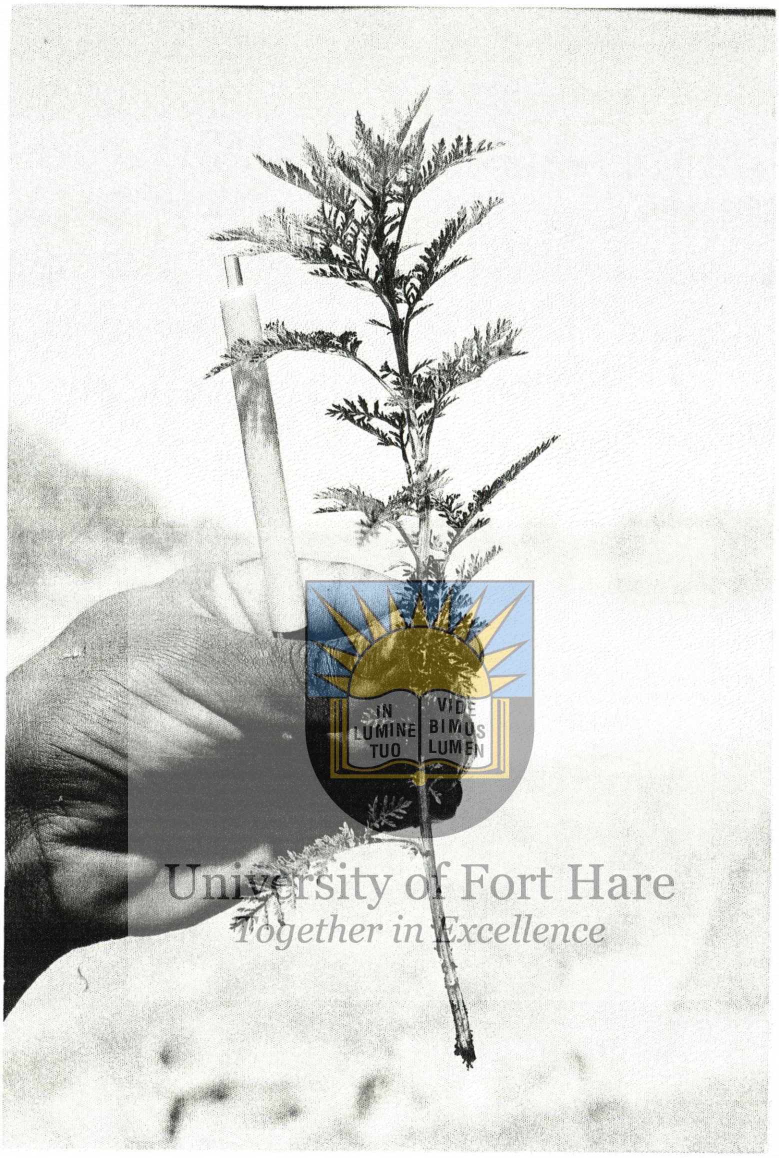

Plate 7.1.1 Cuttings were about 15 cm long with leaves removed on the lower portion and retained on the upper part.

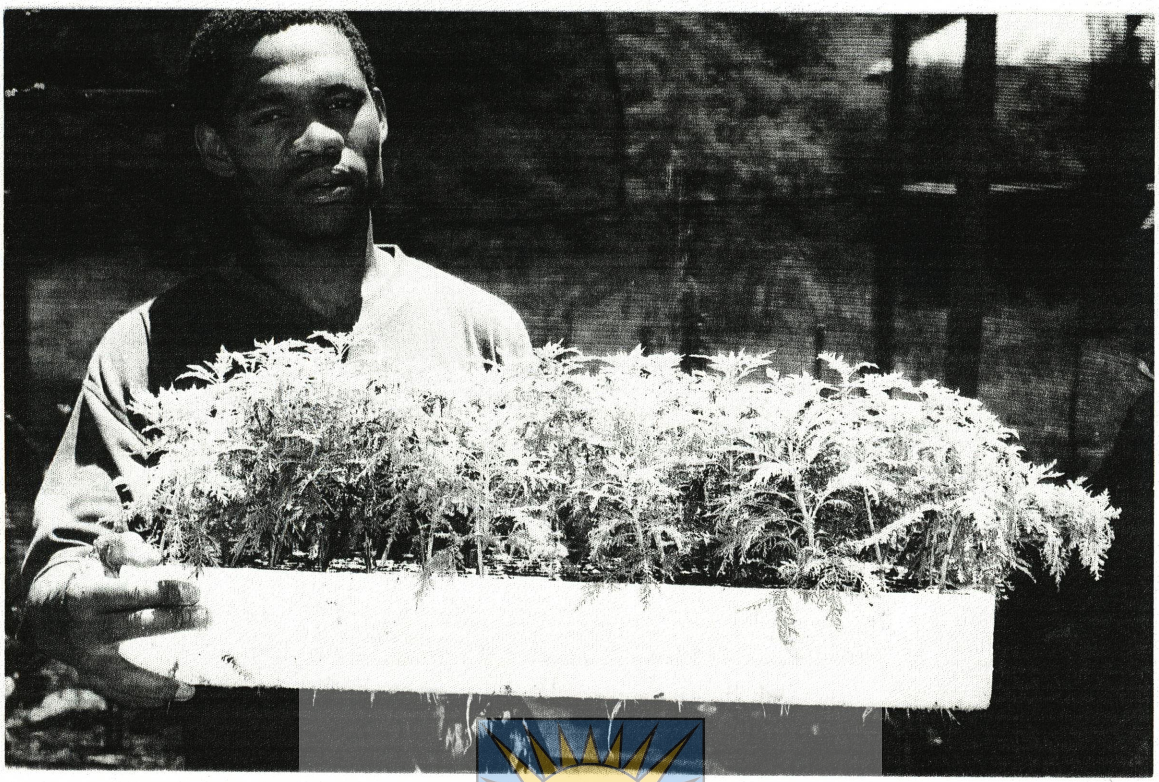

Plate 7.1.2 Appearance of roots beneath 128 cavity Styrofoam planter flat from rooted cuttings after four weeks of propagation in a mixture of sand and palm peat under mist.

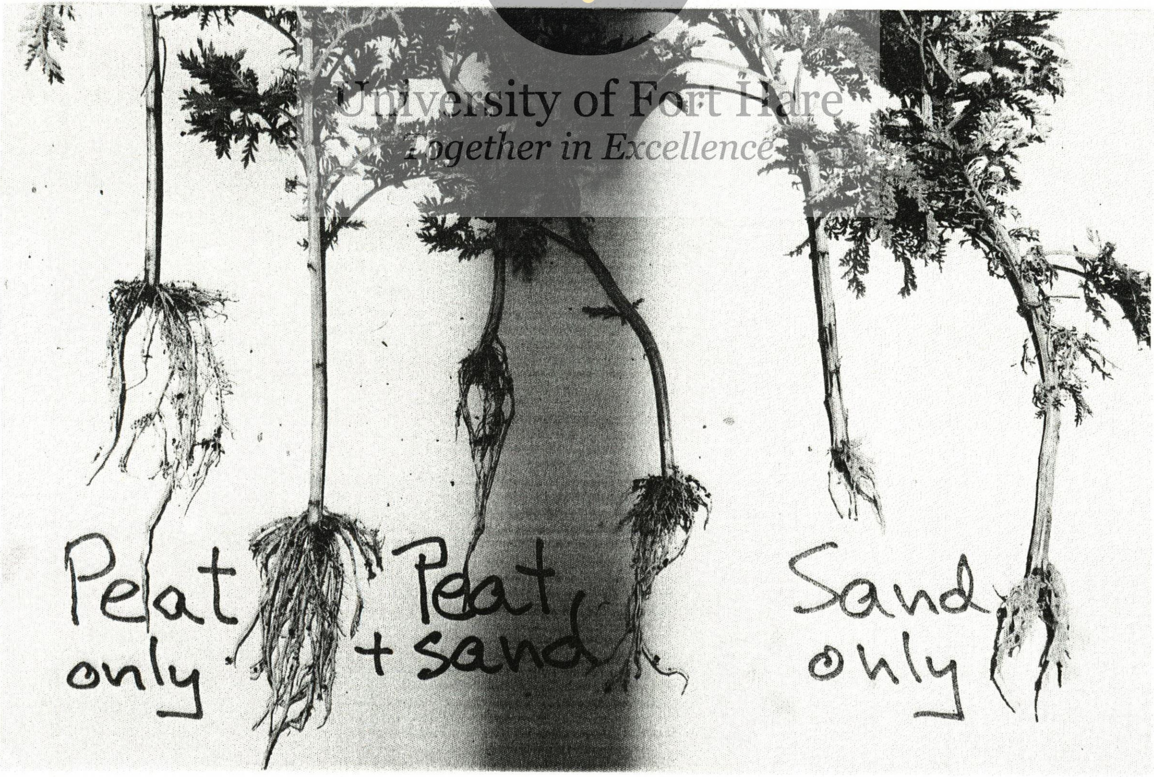

Plate 7.1.3 Poor root development in sand compared to other media after four weeks of propagation.

Plate 7.1.4 Rooted *Artemisia afra* cuttings showing the relatively good adherence of palm peat to the roots and the poor adherence of the sand.

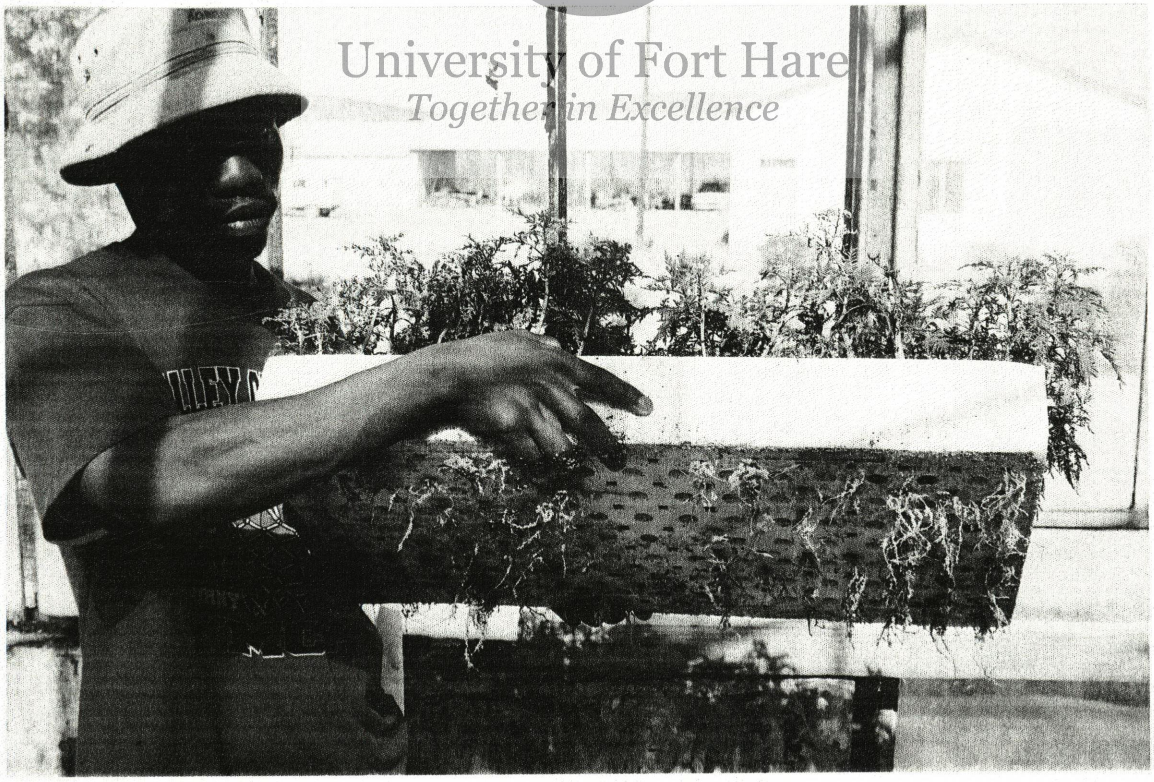

Plate 7.1.5 Appearance of roots of *Artemisia afra* cuttings beneath Styrofoam planter flat after eight weeks of propagation.

Plate 7.1.6 Some cuttings rooted in sand did not develop adventitious roots.

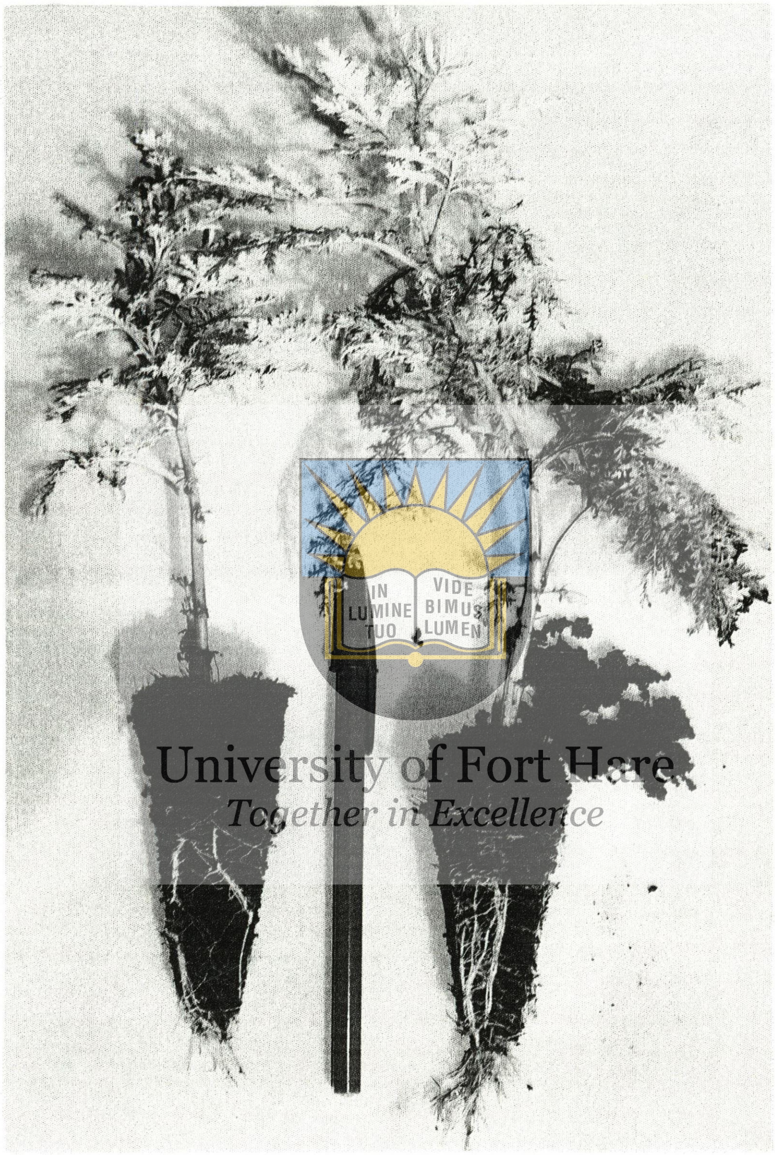

Plate 7.1.7 *Artemisia afra* cuttings rooted in Palm peat pulled out easily from the tray after eight weeks of propagation.

Plate 7.1.8 *Artemisia afra* cuttings rooted in sand were difficult to pull and had little or no medium adhering to the roots.

Plate 7.1.9 *Artemisia afra* cuttings rooted in a mixture of Palm peat and sand pulled out easily still with medium adhering to the roots after eight weeks of propagation.

7.2 Experiment 2. Comparison of different nitrogen and Aqua-fert® levels on rooted cuttings grown in pots.

7.2.1 Introduction

In the past at the University of Fort Hare, rooted cuttings were potted in plastic bags filled with soil because it is fairly readily available and cheaper than commercial growing media. Composted and milled pine bark also have been used successfully. In this trial it was decided to compare a standardized and readily available growing medium with soil and also to use either a specially formulated soluble complete fertilizer mixture or urea to supplement the nitrogen.

The objective of this trial was to compare different levels of nitrogen and different levels of Aqua-fert® on transplanted *Artemisia afra* cuttings growing in either soil or a readily available commercial growing medium, Hygromix®.

7.2.2 Materials and methods

Two hundred cuttings, rooted in 128 cavity Styrofoam planter flats in a mist bed (Plate 7.2.1), were transplanted to 50 pots (13-cm diameter) on 15 November 2000 (Plate 7.2.2). Each pot had four rooted cuttings. Soil and a commercial seedling mixture, Hygromix®, were used as growing media separately (Plates 7.2.3 and 7.2.4). The rooted cuttings in each medium were treated with nitrogen (urea solution), Aqua-fert® solutions and the control received water only. Aqua-fert® is a Hygrotech product which is a complete commercial fertilizer for fertigation that comes in two solutions (Aqua-fert® 1 and Aqua-fert® 2) for mixing with water. Aqua-fert® 1 comprises 7,5%N; 8,58%K; 6,00%Ca and 1,50%Mg, whereas Aqua-fert® 2 consists of 1,50%N; 0,08%Mn; 2,50%P; 0,075%B; 3,40%K; 0,005%Cn; 0,17%S; 0,03%Zn; 0,20%Fe and 0,005%Mo. They were applied at the manufacturer's recommended rate of 25 ml Aqua-fert® per 10 litres water.

The experiment was a randomized complete block design (RCBD), with ten fertilizer treatments and five replications (10 × 5). The treatments were as follows:

- Nitrogen (150 ppm) once per week in the form of urea to a seedling mix.
- Nitrogen (150 ppm) once per week in the form of urea to a soil.
- Nitrogen (150 ppm) three times per week in the form of urea to a seedling mix.
- Nitrogen (150 ppm) three times per week in the form of urea to a soil.
- Aqua-fert® once per week to a seedling mix.
- Aqua-fert® once per week to a soil.
- Aqua-fert® three times per week to a seedling mix.
- Aqua-fert® three times per week to a soil.
- Control, no nitrogen, no Aqua-fert® to a seedling mix.
- Control, no nitrogen, no Aqua-fert® to a soil.

The rooted cuttings were transplanted on 15 November 2000 from the Styrofoam planter flats (polystyrene cavity trays) to the 13 cm pots (Plate 7.2.4). Rooted *A. afra* cuttings were harvested on 16 January 2001, nine weeks after being transplanted. Roots were washed free of medium (Plate 7.2.6). The material was separated into shoots and roots and the samples were oven dried and their dry mass determined. Data was analysed as a randomised complete block design (RCBD) using MSTAT-C program. Means were separated using the LSD test.

7.2.3 Results

Generally speaking, the rooted cuttings transplanted into the commercial seedling mix (Hygromix) survived better than those in soil (Table 7.3) and Plate 7.2.7). Algal growth was abundant on the surface of some pots with soil.

Because some cuttings had died, it was deemed preferable to determine the mean dry shoot and root mass per surviving cutting in each treatment, rather compute it as the mean per treatment, assuming four cuttings per treatment.

The results, in terms of root and shoot dry mass, are presented in Table 7.4 and Appendix F.

7.2.3.1 Shoot Dry Mass

Only in the case of the nitrogen treatments was shoot dry mass better in the seedling mix than in the soil. All Aqua-fert® treatments and the nitrogen plus seedling mix treatments were superior to control treatments.

7.2.3.2 Root Dry Mass

The seedling mix invariably favoured root growth, except where no nutrients were applied where it was not better than in the soil. Best rooting in the seedling mix occurred with the higher nutrient applications. In the soil the response was not evident except with the higher applications of Aqua-fert®.

7.2.3.3 Root Shoot Ratio

There were relatively small and inconsistent differences between treatments, with only the lower levels of nitrogen and Aqua-fert® in the soil medium being significantly inferior to the lower level of Aqua-fert® in the seedling mix and the higher level of Aqua-fert® in the soil.

7.2.3.4 Shoot Mass Ratio

There were no significant differences between the soil treatments receiving additional nutrients. There were no significant differences between soil and Hygromix® treatments receiving the higher levels of Aqua-fert®, the lower levels of nitrogen, and the controls. At the higher nitrogen and Aqua-fert® levels the shoot mass ratio tended to be larger in the soil because of the smaller amount of root growth.

7.2.3.5 Root Mass Ratio

The tendency for the root growth to be better in the seedling mix receiving nutrients is generally reflected as such in the root mass ratio. The exception is with the higher levels of Aqua-fert®.

7.2.4 Discussion and conclusions

Not only is it important to obtain a high rooting percentage and a good root system for *Artemisia afra* cuttings, but equally important is the continued growth of rooted cuttings in pots or in the field, if directly transplanted as rooted "plugs".

Soil on its own can be a problem if it is poorly drained. The soil used in this trial, an Oakleaf, is considered to have a relatively high potential for irrigated crops, although a degree of surface crusting has been noticed. In the trial reported here the soil on its own was found not to be very suitable as a potting mix, as evidenced by the poor drainage and the development of algal growth on the surface. By contrast the commercially available Hygromix, with its tested physical properties, proved to be much more suitable whether or not additional nitrogen or Aqua-fert® (complete soluble fertilizer manufactured by Hygrotech) is used.

Handreck and Black (1984) reported that algal growth is a sign that the medium is remaining too wet for best plant growth. Handreck and Black (1984) also reported that potting mixes with large volume of soil usually have poor aeration, especially in flats and shallow pots. Some of the cuttings growing in soil died because of poor drainage.

These were very preliminary trials which require further investigation, particularly as fertilizer is an expensive commodity which needs to be used economically in propagation. It also needs to be applied very carefully so as to avoid fertilizer "burn" or similar damage to the plant.

The high CV's obtained also limit the reliability of the results and partly explain the absence of clearer trends.

The advantage of rooting cuttings in cavity trays is that a good rooting medium can be used, with proper hardening of the rooted cuttings made easier. The rooted plugs so obtained and properly hardened can lead to a high level of transplanting success or "take" in the field, more so than with bare-rooted cuttings. The need to transplant into bags can thus be avoided in most situations.

The Hygromix® seedling mix is carefully formulated to provide good moisture retention yet allow good aeration. It has an air-filled porosity (AFP) favourable for seedling growth and seems to provide better root growth for rooted cuttings than does the soil used alone.

We are not aware of other reports of similar trials with *A. afra* with which to compare these results.

Table7.3: Total percentage survival of transplanted rooted *Artemisia afra* cuttings in different media and with various treatments.

Treatments	No. of Cuttings potted	No. of cuttings survived	% Survived
Control + Seedling mix	20	19	95
Control + soil	20	12	60
Nitrogen 1/week + Seedling mix	20	11	55
Nitrogen 1/week +Soil	20	9	45
Nitrogen 3/week + Seedling mix	20	16	80
Nitrogen 3/week + Soil	20	14	70
Aqua fert® 1/week + Seedling mix	20	19	95
Aqua fert® 1/week + Soil	20	7	35
Aqua fert® 3/week+ Seedling mix	20	17	85
Aqua fert® 3/week + Soil	20	16	80
TOTAL	200	140	70

Table 7.4: The effect of different fertilizer treatments on rooted *Artemisia afra* cuttings growing in either soil or Hygromix®, a commercial seedling mix.

Treatments	Mean Shoot Dry mass /plant (g)	Mean Root Dry mass /plant (g)	Root Shoot Ratio /plant	Shoot Mass Ratio /plant	Root Mass Ratio /plant
Control + Seedling mix	1.61b	0.34de	0.211ab	0.829cd	0.170ab
Control + soil	2.25b	0.34de	0.132 ab	0.888bcd	0.113bcde
Nitrogen 1/week + Seedling mix	5.15a	0.61cd	0.145ab	0.904abc	0.121abc
Nitrogen 1/week +Soil	2.48b	0.19e	0.067 b	0.937ab	0.061de
Nitrogen 3/week + Seedling mix	5.32a	1.04ab	0.195ab	0.839cd	0.160ab
Nitrogen 3/week + Soil	2.75b	0.21e	0.073 ab	0.935ab	0.073cde
Aqua fert® 1/week + Seedling mix	6.83a	1.40a	0.209 a	0.828cd	0.172ab
Aqua fert® 1/week + Soil	5.69a	0.31de	0.052 b	0.978a	0.048e
Aqua fert® 3/week+ Seedling mix	6.35a	1.34a	0.239ab	0.813d	0.187a
Aqua fert® 3/week + Soil	5.48a	0.78bc	0.442a	0.861bcd	0.138abc
LSD 0.05	2.240	0.385	0.319	0.081	0.070
CV %	39.78	45.77	53.87	6.99	45.52

Means followed by the same letter do not differ significantly from each other ($P \leq 0.05$), LSD test.

Plate 7.2.1. *Artemisia afra* cuttings were rooted in 128 cavity Styrofoam planter flats.

Plate 7.2.2. *Artemisia afra* cuttings transplanted into plant pots.

Plate 7.2.3. Rooted cuttings growing in soil.

Plate 7.2.4. Rooted cuttings growing in commercial seedling mix.

Plate 7.2.5. The *Artemisia afra* cuttings in 13 cm plant pots.

Plate 7.2.6. Roots of cuttings were washed free of medium.

Plate 7.2.7 *Artemisia afra* cuttings transplanted in commercial seedling mix performed better than those transplanted in soil.

Plate 7.2.8. The cuttings treated with Nitrogen were better than control (no applied nutrients).

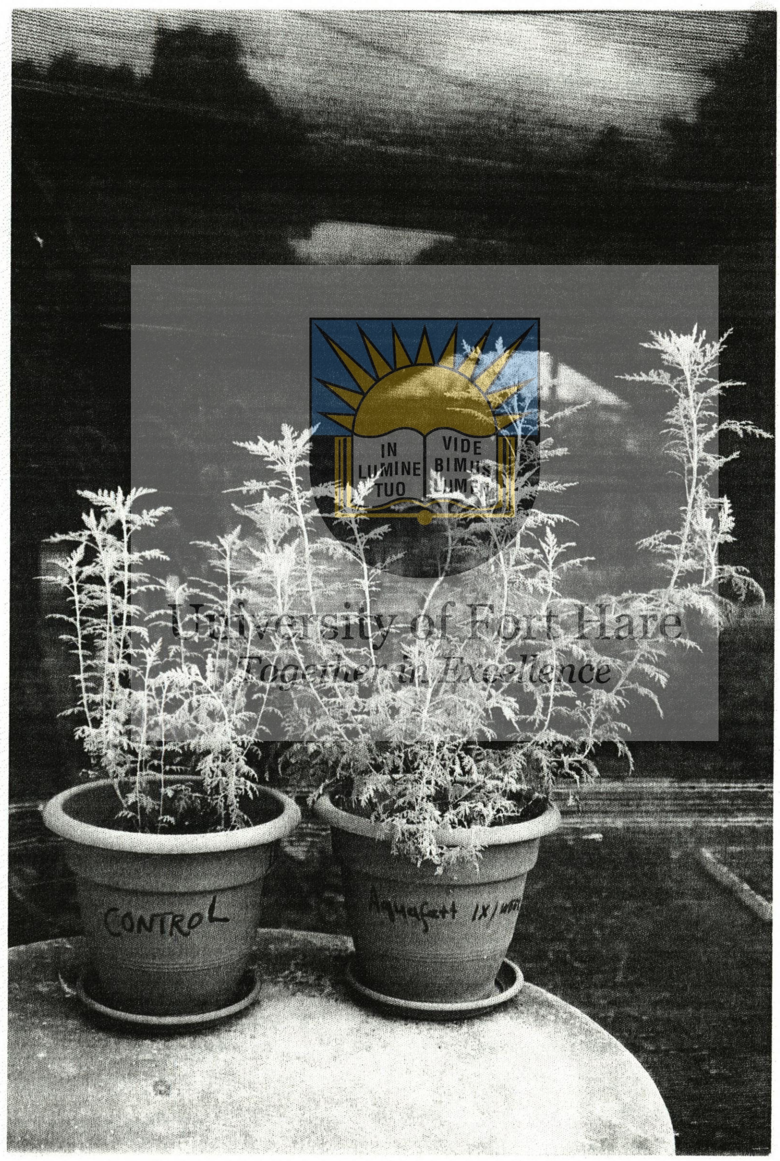

Plate 7.2.9. Aqua-fert® (Right) treatments were better than control (Left).

Plate 7.2.10. There were no visible differences between control plants (no applied nutrients) in soil and in Hygromix®.

Plate 7.2.11. Algal growth was abundant on the surface of pots with soil.

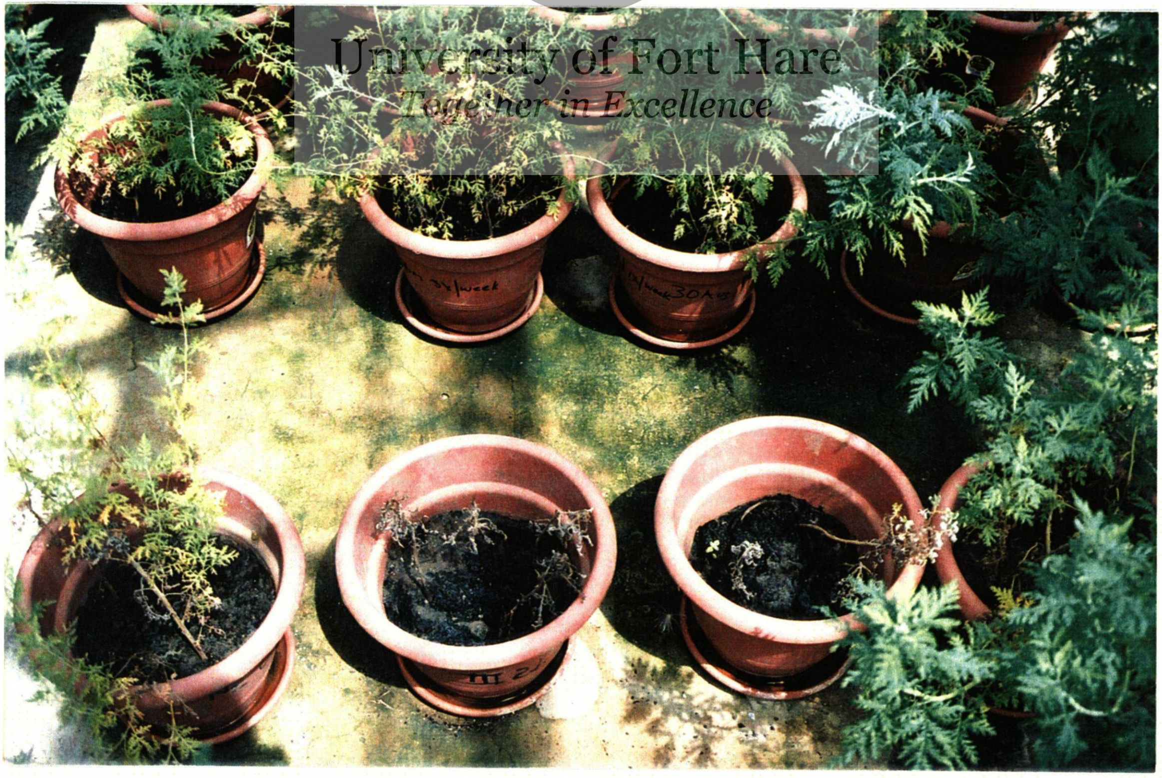

Plate7.2.12.Some *Artemisia afra* cuttings transplanted in soil died due to poor drainage.

Plate 7.2.13. Some cuttings died later after prolonged periods of poor drainage in soil.

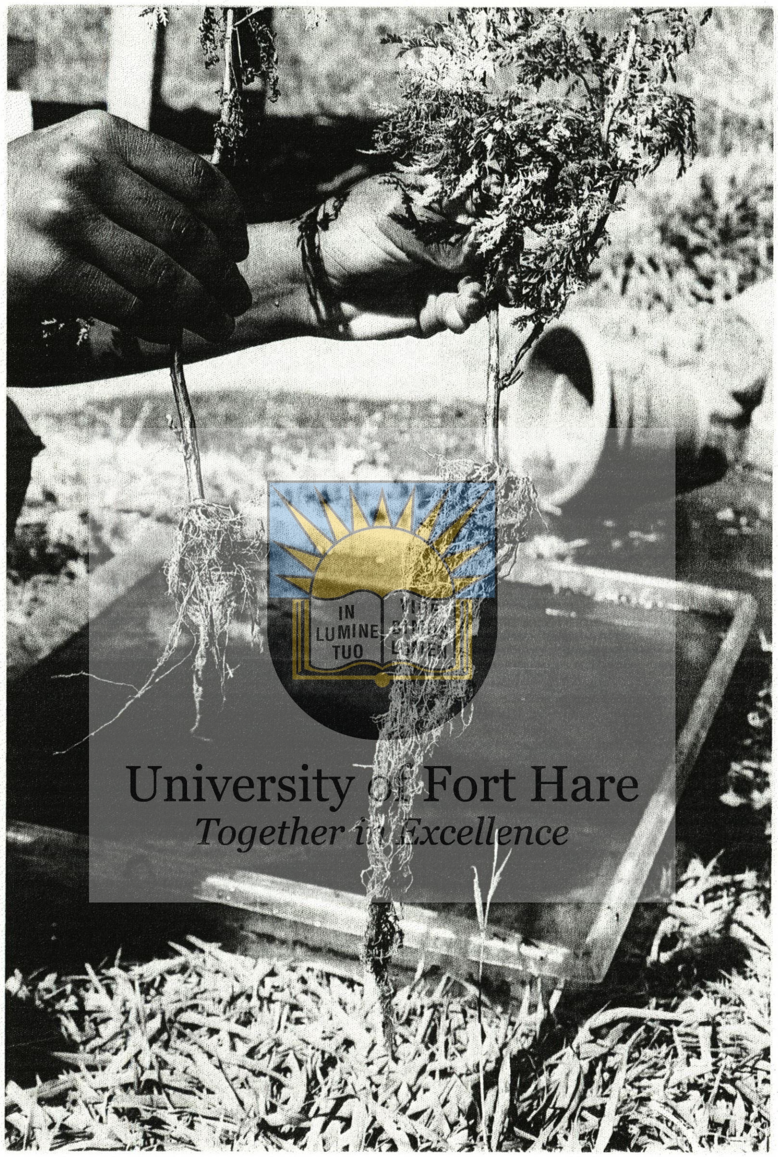

Plate 7.2.14. Better root length of rooted *Artemisia afra* cuttings grown in the commercial seedling mix.

7.3 **Experiment 3. The effect of PBZ and IBA on *Artemisia afra* cuttings**

7.3.1 Introduction

Triazoles, including paclobutrazol (PBZ), are the most potent group of growth retardants but also have many other related reactions, especially those related to various forms of stress protection. Physiological changes induced by triazoles include improved water status and protection from various biotic and abiotic stresses, including fungal pathogens, drought, and low and high temperatures (Fletcher, Gilley, Sankhla and Davis, 2000).

Some triazole compounds, including PBZ, have been found to be effective in promoting the formation of adventitious roots in plant cuttings (Davis and Sankhla, 1986, cited by Fletcher *et al.*, 2000). Fletcher *et al.* (2000) also refer to the work of Pan and Zhao (1994), which suggests a synergistic effect on rooting of PBZ and IBA. The former authors also provide evidence that a higher root-to-shoot ratio in PBZ treated plants is commonly due to the drastic reduction in shoot growth.

Bearing in mind the potential benefits of PBZ on the rooting and survival of *A. afra* leafy stem cuttings it was decided to apply a solution of PBZ at the recommended rate to the entire cutting, with or without subsequent treatment of the base of the cutting with IBA.

The aim of this experiment was to compare the effectiveness of paclobutrazol (PBZ) and IBA, singly and in combination, on rooting of *Artemisia afra* softwood cuttings. The rooting medium which was used for this experiment was a mixture of palm peat and sand in a ratio of 1:1 by volume.

7.3.2 Materials and methods

The cuttings were rooted in a mixture of sand and palm peat in 1:1(v/v) ratio using standard polystyrene trays with 128 cavities. Cuttings about 15 cm long were made on 15 January 2001. A clean cut was made just below a node and leaves were removed from the lower third of each cutting (with those on the upper part retained). As soon as the cut was made, cuttings were treated with a commercial preparation of rooting powder and PBZ solution.

The trial was laid out as a randomised complete block design (RCBD) with two IBA levels, two PBZ levels (with active ingredient of 250 g/l) and four replications (2 ×2 × 4=16 trays). PBZ was applied at the recommended rate. Seradix® No.1 (IBA) is a hormone powder for the stimulation of rapid and prolific rooting of softwood plant cuttings (active ingredient: indole butyric acid, 1g/kg). Polystyrene trays with 128 cavities were cut into two halves, each with 56 cavities as the two middle cavities rows of were damaged during the cutting process. Therefore each tray consisted of 56 cuttings (one half of a cavity tray) of which the perimeter cuttings were considered to be the guard rows and therefore not for sampling. The treatments were as follows:

- Cuttings were briefly immersed in a solution of 25 ppm PBZ.
- Cuttings were briefly immersed in a solution of 25 ppm PBZ and the base of each cutting was treated with Seradix® No.1 (IBA) powder before being placed in the mist bed for rooting (PBZ + IBA).
- Cuttings were briefly immersed in water (without PBZ) and the base of each cutting treated with Seradix® No.1 powder before being placed in the mist bed for rooting (IBA).
- Cuttings were briefly immersed in water (without PBZ or subsequent IBA, treatment) before being placed in the mist bed for rooting (control).

The cuttings were given enough time to develop roots and after five weeks, on 29 February 2001, fifteen cuttings from each tray were selected randomly. The rooting medium was carefully washed away to leave the root system intact. The root length on selected cuttings was determined and rated visually as "very good to good" and "very little to no rooting". The disease status on leaves was also determined as "disease free", "minor infections" and "substantial infections".

7.3.3 Results

Table 7.5 shows the rooting observations. The first roots appeared below the trays after three weeks. Plates 7.3.2, 7.3.3 and 7.3.4 show the rooting of *Artemisia afra* cuttings after five weeks. All three treatments produced equally good rooting, and all were apparently somewhat superior to the control treatment (plate 7.3.3). Only one rootlet had formed at the base of some cuttings (plate 7.3.4).

Visual observations (Table 7.6 and Plates 7.3.3 and 7.3.5) suggest that PBZ may indeed have a beneficial effect on disease control but these were very preliminary trials only.

Table 7.5 Visual rating of root development on *Artemisia afra* cuttings treated with PBZ and IBA alone or in combination.

Treatment	Total no. of cuttings	Very good –good rooting (no.)	Very good-good rooting (%)	Very little – no rooting (no.)	Very little-no rooting (%)
PBZ	60	49	82	11	18
IBA	60	48	80	12	20
PBZ + IBA	60	47	78	13	22
Control	60	40	67	20	33

Table 7.6 Visual rating of disease status on *Artemisia afra* cuttings with and without PBZ treatment.

Treatment	Total no. of cuttings	Free (no.)	Free (%)	Minor infection (no.)	Minor infection (%)	Substantial infection (no.)	Substantial infection (%)
PBZ	60	24	40	35	58	1	2
IBA	60	21	35	37	62	2	3
PBZ+ IBA	60	33	55	24	40	3	5
Control	60	21	35	38	63	1	2

7.3.4 Discussion and conclusions

These preliminary trials suggest that PBZ and IBA applied alone or in combination may improve the rooting of *A. afra* leafy cuttings. PBZ may possibly ensure healthier rooted cuttings, which supports similar observations made with cuttings of other plants and re-enforces the fungicidal properties of this growth retardant. The cuttings were not kept long enough to allow sufficient growth to develop and show up any growth-retarding effects of PBZ. The effects of PBZ on *A. afra* need to be researched more fully, both for cuttings and for plant growth control in the field. These are assumed to be the first trials with PBZ and *A. afra* as no other trials have been reported in the literature.

Plate 7.3.1 Root growth of untreated (control) cuttings was not good. Left: Control; Middle: PBZ alone; Right: PBZ plus IBA.

Plate 7.3.2 *Artemisia afra* cuttings treated with PBZ and IBA were healthier.

Plate 7.3.3 Disease infection on *Artemisia afra* cuttings treated with IBA alone.

Plate 7.3.4 Some minor disease infections on cuttings treated with PBZ alone.

8. OVERALL DISCUSSION AND CONCLUSIONS

This study has been concerned with the domestication of *Artemisia afra* by local farmers and the community in Melani village, near Alice in the Eastern Cape. Research on essential oils has been undertaken at the University of Fort Hare for over 25 years and there is a commercial essential oils processor very near Melani village.

There were two components to the research project. In the first place a survey was undertaken with the people at Melani village to ascertain their knowledge of *A. afra* and their interest in domesticating it. Secondly, there was interest in better understanding the vegetative propagation of this plant. From previous unpublished work done with *A. afra* at University of Fort Hare it was clear that the rooting of leafy cuttings under mist gave good results. Some difficulty has been experienced with propagation from seed and there is evidence of both light and cold stratification being beneficial for germination. Clonal propagation is preferred, however, particularly if desirable clones are identified and need to be mass propagated.

The survey revealed that *A. afra* (Mhlonyane) is known to the Melani community and has been used as a traditional medicinal plant to treat fever, coughs, headaches and colds. The plant material is obtained from the wild. There is a local need for development and job creation, and an essential oils industry in the region could be greatly beneficial.

It would not be necessary, initially at least, for the community to have its own still as such facilities exist at the University of Fort Hare, (although not used at present) and there is a neighbouring commercial farmer in the Tyume Valley who distils essential oils.

The community is in a position to benefit from the educational institutions in Alice, and also from Phandulwazi Agricultural High School, some 5 km away.

The climate is very favourable for the growing of Mhlonyane and the regular supply of water of good quality in the Tyume River (released from the nearby Binfield Dam) could enable supplementary irrigation on irrigable soils.

Transport of plant material to the distillation plants would be relatively easy and economical because of the reasonable distance from the potential cultivation sites at Melani and because of a reasonable road network.

A major advantage of *A. afra* is the fact that it is not palatable to livestock. Nor is there much of a market for it in an unprocessed form, which means theft will not be a problem.

Marketing of essential oils is very specialized and depends largely on international contacts and demand for the oil. Fortunately, there is a good demand for the oil of *A. afra* (H.T. Gxotiwe, personal communication with M.O. Brutsch) and Mr. Gxotiwe, the local commercial farmer and processor of *Tagetes* and other essential oils, would be a willing co-operator.

Obviously other aspects need to be investigated, such as start-up capital and managerial expertise for a substantial and economic essential oils industry based on *A. afra* and possibly other essential oils crops.

Although a considerable amount of research on *Artemisia afra* as an essential oil crop has been done at the University of Fort Hare there would be a need for more research on an ongoing basis and in conjunction with the University of Fort Hare and other interested parties. It is a stated policy of the University of Fort Hare to become more involved in community outreach/ community partnerships so that assistance from this source can be expected.

Clonal propagation of *A. afra* is preferable in most situations to seed propagation. Fortunately it seems to propagate readily from leafy stem cuttings under mist. Such a facility is rather costly but otherwise easy to manage. The trials conducted in this study with the vegetative propagation of *A. afra* were very much of a preliminary nature and need to be followed.

Because *A. afra* cuttings root readily it seems that the concentration of IBA used is not critical and the commercial powder/talc formulations work well and are easy to apply.

Growing media make a difference to rooting and ease of pulling of rooted "plugs" and it is important that the plugs remain intact and do not disintegrate as they do when sand is used alone. Economic considerations and availability of the medium are important factors. The use of cavity trays is not essential but does make for ease of propagation and transplanting. Plant manipulation is also much easier, including hardening prior to transplanting.

With cavity trays good rooted cuttings can be produced for direct transplanting in the field. Where on the other hand, such cuttings are rooted in the rooting medium in the mist bed (without cavity trays) it is usually necessary to transplant them into plant bags in a suitable growing medium. Soil is often used.

This study showed clearly that even what is considered to be good soil in the field can be a problem when used alone in a bag, because of poor drainage in such a situation. It is preferable to use a good potting medium but it is more expensive. Otherwise the physical properties of the soil should be improved with the addition of a medium such as pine bark. The advantage of a good commercial growing medium such as Hygromix® is its good physical properties and consistency in quality.

The nutrient solution applied in the pot will depend to a large extent on the growing medium used. Some media are pre-enriched with selected nutrient elements. Good results were obtained with Aqua-fert®, marketed by Hygrotech® who also market Hygromix®. There are many other such products produced by different manufactures. It is important to reduce costs as much as possible so the economic level of fertigation would have to be determined through further trials.

It is much more economical to eliminate the potting step and grow "plugs" which can then be transplanted directly in the field. Crop hardening and crop manipulation, if necessary, is then also more easily managed in cavity trays.

Paclobutrazol (PBZ) has been used effectively to manipulate the growth of tomato seedlings at the University of Fort Hare (Brutsch, personal communication, 2000). Sturdier, better coloured seedlings have been produced. The potential benefits of PBZ and other triazole compounds have been reviewed by Fletcher *et al.* (2000) and were briefly outlined under 2.2.3.2 and 7.3.1. From our preliminary trials it seems PBZ may not improve rooting of cuttings but alone, or in combination with IBA, it may keep treated plants healthier than control plants or those treated with IBA alone. Synergistic effects of IBA and PBZ on rooting were reported by Pan and Zhao (1994, cited by Fletcher *et al.*, 2000). In our trials the synergistic effect may have been expressed in terms of plant health but further investigation would be necessary to verify this.

Vegetative propagation of leafy cuttings of *A. afra* under mist is economically viable but it is only with further research that the technique can be refined.

Although the survey was conducted at Melani village, because of its proximity to University of Fort Hare and the commercial enterprise of Mr. H. T. Gxotiwe, other communities in the area would no doubt also be interested in a local essential oils industry, if it were to develop and provide opportunities for socio-economic development. Indeed, the University of Fort Hare is interested in promoting such development and project proposals have been drawn up for funding (Brutsch, personal communication, 2002).

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10. APPENDIX-A

QUESTIONNAIRE -TO FARMERS AND COMMUNITIES

DOMESTICATION OF *ARTEMISIA AFRA* (AFRICAN WORMWOOD)

Researcher	Mr. C. N. Ketelo
Date	……………/……….. ………………/2000
Village	
Questionnaire no.	

1.DEMOGRAPHIC CHARACTERISTICS

1.1 Name of respondent……………………………………………………………………………………………

1.2 Sex of respondent

1=M	2=F

1.3 Marital status

1=MARRIED	2=SINGLE
3= DIVORCED	4= WIDOW/ER

1.4 Head of the household

1= HUSBAND	2=WIFE	3=SON
4= DAUGHTER	5= OTHER	

1.5 Household size………number of

1=M	2=F

1.6 Occupation status of household

1= Self employed	2=Employed away	3=Commuter daily
4=Student	5= Commuter weekly	6= Other

1.7 Formal education- years at school……………

1.8 What status do you hold in the community?

1=Chief	2=Headman	3= Committee member
4= Councilor	5= Ordinary person	6= Other

1.9 State of your health

1=Good	2=Fair	3=Poor

2. RESEARCH CROP

2.1 What is the local name of African wormwood (Artemisia afra)?

....

2.2 Do you regard it as a weed?

1=Yes	2= no

2.3 What do you use this plant for at present?

....

2.4 Do you know any medicinal use of this plant?

For people

1= Yes	2= No

For animals

1= Yes	2=No

2.5 If yes in any of the above, give details.

For people..

....

For animals..

....

2.6 Have you ever harvested any part of African wormwood (Artemisia afra)?

1= Yes	2= No

2.7 Which part of plant did you harvest/ use?

1= Seeds
2= Flowers
3= Leaves
4= Stem
5= Roots
6= Whole plant

2.8 What equipment did you use to harvest the plant?

....

2.9 In which season do you think it is suitable to harvest the African wormwood? ....

....

2.10 Give reasons, why do you choose that season?

....

....

2.11 Have you ever tried to grow this plant?

1= Yes	2= No

2.12 If yes, was it by

Seeds
Vegetatively
Dig out plant

2.13 How long does it take to grow?

....

2.14 Have you ever noticed an increase in the number of plants over the years?

1= Yes	2= No

2.15 What diseases, pests or insects are common to this plant?

....

2.16 Are there any traditions or beliefs, which prohibit the harvesting of this Plant?

1= Yes	2= No

2.17 If yes, what are they?

....

....

2.18 Do you find this plant in the veld?

1= Yes	2= No

2.19 Do you domesticate this plant?

1= Yes	2=No

2.20 What is the reason for your answer, in brief?

....

....

2.21 Are there any factors, which prohibit the domestication of this plant?

1= Yes	2=No

2.22 If yes, what are they?

....

....

2.23 Are you aware of the oil, which can be extracted from this plant?

1= Yes	2= No

2.24 Do you know how is the oil extracted?

1= Yes	2= No

2.25 Do you know any use of this oil?

1= Yes	2= No

2.26 If yes, what is it used for?

....

....

3. ARABLE LAND

3.1 What is the total area of your land? .... Ha.

3.2 What are the land rights you have?

....

....

3.3 Are you satisfied with the way land is allotted in your area?

1= Yes	2= No

3.4 If no, give reasons

....

....

3.5 What is the land use on Arable land?

LAND -USE	AREA (Ha)
Horticultural crops	
Field crops	
Fallow	
Other	

3.6 What is the present land tenure system in your community?

1= State owned
2= Communal
3= Free hold
4= Other (specify)

4. LABOUR

4.1 Do you have sufficient labour for your farming?

1= Yes	2=No

4.2 If no, how do you manage to solve the problems most of the time?

1= Working long hours
2= Employ people
3= Ask help from relatives/neighbours
4= Other

4.3 Do you normally get labour assistance from your family for farming activities?

1= Yes	2= No

4.4 If yes, how often?

....

4.5 If no, why?

....

....

4.6 What about your children?

1= Yes	2= No

4.7 What kind of assistance do they offer?

....

....

5. COMMUNICATION

5.1 Where do you get information on farming (agriculture)?

....

....

5.2 Are you satisfied with present source of information?

1= Yes	2= No

5.3 If no, what are your suggestions for improvement?

....

....

5.4 Do you read agricultural news in the newspapers, pamphlets or magazines?

1= Yes	2= No

5.5 If no, why?

....

....

5.6 Do you listen to agricultural news on the radio?

1= Yes	2= No

5.7 If yes, are you benefiting from these programs?

1= Yes	2= No

5.8 Do you get advice from the extension officers regarding the production of essential oil plants (eg. African wormwood, Blue bush, Tagetes minuta)?

1= Yes	2= No

5.9 Do you have a telephone in your home?

1= Yes	2= No

6. MARKETING

6.1 Are there any markets for African wormwood plant?

1=Yes	2= No	3= Don't know

6.2 Would you be interested in the marketing of this plant?

1= Yes	2= No

6.3 If yes, what kind of assistance would you need?

....

....

6.4 Would you be willing to harvest and sell African wormwood to someone who would extract the oil?

1= Yes	2= No

6.5 If no, why

....

....

6.6 Would you be keen to extend the propagation of the plants for increased sales?

1= Yes	2= No

7. PERCEPTIONS AND ATTITUDES

7.1 What do you consider to be the most important use of this?

....

....

7.2 What problems do you think you can encounter with production and domestication of essential oil plants?

....

....

7.3 Do you think domestication of African wormwood be prohibited by your traditions?

....

....

7.4 Would production of essential oil be beneficial to your community?

....

....

7.5 Do you think domestication and production of essential oil can uplift the standard of living in your area?

....

....

7.6 What kind of development would you like to see first in order to start an essential oil Company in your area?

....

....

8. INFRASTRUCTURE

8.1 Where do you get water to irrigate your plants?

1= Rainfall
2= Water taps
3= River
4= Dam
5= Other(specify)

8.2 What is the condition of road in your area?

1= Good	2= Fair	3= Bad

8.3 Is transport available to carry your material to the nearest distillation unit?

1= Yes	2= No

8.4 What type of transport is available?

....

....

8.5 Are your fields fenced?

1=Yes	2 =No

9. INSTITUTIONAL SUPPORT

9.1 Have you ever-visited research station or institutions dealing with essential oil plants (eg Fort Hare research farm)?

1= Yes	2= No

9.2 If yes, how many times have you visited?

....

9.3 How did you find the visit?

1=Very useful learnt so much
2= Useful learnt much
3= Fairly useful learnt something
4= Not too good did not learn much
5= Useless I learn nothing

9.4 Would you like to have another visit?

1= Yes	2= No

9.5 What is the reason for your answer in brief?

....

....

9.6 Is there any local farmers association dealing with essential oil in your area?

1= Yes	2= No	3 = Don't know

9.7 To which farmer's organization do you belong?

....

....

9.8 What benefits do you get from being a member of the organization?

....

....

9.9 Which institution do you think would most probably help promote essential oil production in your area?

....

....

9.10 Have you ever attended a farmer's day?

1= Yes	2= No	3= I don't have an idea

9.11 If yes, how many times?

....

....

9.12 How did you find the farmers day?

1= Very interesting learnt so much
2= Interesting learnt much
3= Interesting did learn something
4= Not too interesting did not learn much
5= Useless I learn nothing

9.13 Would you like to attend other farmer's days?

1= Yes	2= No

9.14 If never attended farmers day, would you like to attend someone in the future?

1= Yes	2= No

10. FELT NEEDS

10.1 What are your needs to establish essential oil production?

....

....

10.2 What are your needs to improve community life?

....

....

10.3 What are your needs to uplift your standard of living?

....

....

APPENDIX-B

Root characteristics of *Artemisia afra* cuttings treated with IBA on different rooting media

Replicate	Treatments	Root Dry Mass (mg)
1	Sand +Seradix No.1	24.00
1	Sand plus Palm peat + Seradix no.1	44.00
1	Palm Peat + Seradix No. 1	52.67
1	Sand + Seradix No. 2	46.00
1	Sand plus peat +Seradix No.2	47.33
1	Palm Peat + Seradix No.2	42.00
2	Sand + Seradix No.1	26.67
2	Sand plus peat + Seradix No.1	42.27
2	Palm Peat + Seradix No.1	49.33
2	Sand + Seradix No.2	26.67
2	Sand + Palm peat	36.00
2	Palm Peat + Seradix No.2	38.32
3	Sand + Seradix No.1	28.22
3	Sand plus palm peat + Seradix No.1	40.00
3	Palm Peat + Seradix No.1	36.67
3	Sand + Seradix No.2	25.06
3	Sand plus Palm peat + Seradix No.2	40.67
3	Palm Peat + Seradix No.2	46.67

APPENDIX-C

Data file:
Title: Root characteristics of *Artemisia afra* cuttings with IBA treatment on different media

Function: FACTOR

Experiment Model Number 7:
One Factor Randomized Complete Block Design

Data case no. 1 to 18.

Factorial ANOVA for the factors:
Replication (Var 1: Rep) with values from 1 to 3
Factor A (Var 2: Treatment) with values from 1 to 6

Variable 3: DRM
Grand Mean = 38.475 Grand Sum = 692.550 Total Count = 18

T A B L E O F M E A N S

1	2	3	Total
1	*	42.667	256.000
2	*	36.543	219.260
3	*	36.215	217.290
*	1	26.297	78.890
*	2	42.090	126.270
*	3	46.223	138.670
*	4	32.577	97.730
*	5	41.333	124.000
*	6	42.330	126.990

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	2	158.454	79.227	2.1262	0.1700
2	Factor A	5	837.714	167.543	4.4962	0.0208
-3	Error	10	372.629	37.263		
	Total	17	1368.797			

Coefficient of Variation: 15.87%

$s_{\bar{y}}$ for means group 1: 2.4921 Number of Observations: 6

$s_{\bar{y}}$ for means group 2: 3.5243 Number of Observations: 3

APPENDIX-D

Pulling of *Artemisia afra* rooted cuttings treated with IBA on different rooting media from Styrofoam planter flats

Treatments	Replication	No. Pulled	No. Intact	% Intact	No. Partially Intact	% Partially Intact	No. Broken	% Broken
Sand + Seradix® no.1	1	10	0	0	4	40	6	60
	2	10	0	0	7	70	3	30
	3	10	-	-	-	-	-	-
Total		**30**	**0**	**0**	**11**	**55**	**9**	**45**
Sand + Seradix® no.2	1	10	1	10	6	60	3	30
	2	10	0	0	4	40	6	60
	3	10	-	-	-	-	-	-
Total		**30**	**1**	5	**10**	**50**	**9**	**45**
Sand plus Palm peat + Seradix® no.1	1	10	8	80	2	20	0	0
	2	10	7	70	2	20	1	10
	3	10	7	70	2	20	1	10
Total		**30**	**22**	73	**6**	**20**	**2**	7
Sand plus Palm peat + Seradix® no. 2	1	10	8	80	1	10	1	10
	2	10	9	90	1	10	0	0
	3	10	7	70	1	10	2	20
Total		**30**	**24**	**80**	**3**	**10**	**3**	**10**
Palm peat + Seradix® no.1	1	10	5	50	2	20	3	30
	2	10	8	80	2	20	0	0
	3	10	9	90	1	10	0	0
Total		**30**	**22**	**73**	**5**	**17**	**3**	**10**
Palm peat + Seradix® no.2	1	10	8	80	0	0	2	20
	2	10	10	100	0	0	0	0
	3	10	10	100	0	0	0	0
Total		**30**	**28**	**93**	**0**	**0**	**2**	7

APPENDIX-E

Shoot-Root characteristics of *Artemisia afra* treated with different nitrogen and Aqua-fert® levels on two rooting media.

Rep	Treatment	Shoot Fresh wt. (g)	Root Fresh wt.(g)	Dry Shoot wt.(g)	Dry Root wt. (g)	Root shoot Ratio	Shoot Mass Ratio	Root Mass Ratio
1	1	3.28	0.49	1.31	0.16	0.122	0.891	0.109
1	2	7.49	1.85	2.75	0.43	0.156	0.865	0.135
1	3	14.57	1.69	5.19	0.46	0.089	0.919	0.081
1	4	21.38	6.44	8.46	1.61	0.190	0.840	0.160
1	5	22.53	8.97	7.96	1.63	0.205	0.830	0.170
1	6	4.49	0.59	2.56	0.23	0.090	0.918	0.082
1	7	0.86	0.12	0.49	0.03	0.061	0.942	0.058
1	8	0.74	0.15	0.48	0.03	0.063	0.941	0.059
1	9	16.42	1.27	6.38	0.60	0.094	0.914	0.086
1	10	18.85	0.68	6.99	0.23	0.036	0.965	0.035
2	1	2.97	2.03	1.42	0.43	0.303	0.768	0.232
2	2	13.80	3.76	5.31	0.60	0.113	0.898	0.102
2	3	9.92	5.78	3.60	0.69	0.192	0.839	0.161
2	4	15.49	6.27	5.52	1.40	0.254	0.798	0.202
2	5	19.51	4.14	6.49	1.00	0.154	0.866	0.134
2	6	5.60	4.39	2.55	0.66	0.259	0.794	0.206
2	7	4.31	0.45	2.45	0.17	0.094	0.91	0.083
2	8	8.45	0.82	3.46	0.69	0.199	0.834	0.166
2	9	12.26	0.62	8.74	0.16	0.018	0.982	0.018
2	10	10.11	1.34	4.15	0.61	0.147	0.870	0.128
3	1	4.57	1.40	1.54	0.21	0.136	0.880	0.120
3	2	27.69	1.13	8.60	0.37	0.043	0.959	0.041
3	3	17.63	6.84	6.23	1.35	0.217	0.822	0.178
3	4	19.38	9.09	6.27	1.63	0.259	0.794	0.206
3	5	10.00	8.01	2.89	1.27	0.439	0.693	0.305
3	6	4.71	1.11	1.90	0.20	0.105	0.905	0.095
3	7	13.37	2.52	4.90	0.63	0.129	0.886	0.114
3	8	6.93	0.74	2.85	0.16	0.056	0.947	0.053
3	9	15.29	1.53	5.57	0.28	0.050	0.952	0.048
3	10	7.86	5.69	2.95	1.06	0.359	0.736	0.264
4	1	5.51	2.22	1.76	0.48	0.273	0.786	0.214
4	2	10.53	8.03	3.58	1.04	0.291	0.775	0.225
4	3	17.44	9.90	5.38	1.59	0.296	0.772	0.228
4	4	22.42	8.11	6.61	1.23	0.186	0.843	0.157
4	5	29.42	8.17	7.85	0.99	0.126	0.888	0.112
4	6	8.56	4.36	3.22	0.60	0.186	0.843	0.157
4	7	4.18	0.29	1.60	0.05	0.031	0.970	0.030
4	8	5.98	0.98	3.46	0.12	0.035	0.966	0.074

4	9	16.33	3.66	6.48	0.47	0.082	1.055	0.071
4	10	23.39	8.91	7.44	1.13	1.52	0.868	0.132
5	1	4.70	2.57	2.02	0.43	0.213	0.824	0.176
5	2	13.72	2.63	5.50	0.63	0.121	1.022	0.104
5	3	15.15	4.57	6.21	1.13	0.182	0.846	0.154
5	4	18.96	1.83	7.31	1.14	0.156	0.865	0.135
5	5	18.36	6.79	6.57	1.79	0.272	0.786	0.214
5	6	1.47	0.07	1.03	0.02	0.019	0.981	0.019
5	7	6.68	0.46	2.94	0.06	0.020	0.980	0.020
5	8	7.14	0.22	3.48	0.05	0.014	0.986	0.014
5	9	2.93	0.21	1.29	0.02	0.016	0.985	0.015
5	10	16.53	3.94	5.89	0.89	0.151	0.867	0.131

TREATMENTS

1 = Control plus seedling mix.

2 = Control plus soil.

3 = Nitrogen (150 ppm) once per week in the form of urea plus seedling mix.

4 = Nitrogen (150 ppm) once per week in the form of urea plus soil.

5 = Nitrogen (150 ppm) three times per week in the form of urea plus seedling mix.

6 = Nitrogen (150 ppm) three times per week in the form of urea plus soil.

7 = Aqua-fert® once per week plus seedling mix.

8 = Aqua-fert® once per week plus soil.

9 = Aqua-fert® three times per week plus seedling mix.

10 = Aqua-fert® three times per week plus soil.

APPENDIX-F

Data file:

TRANSPLAC
Title: SHOOT-ROOT CHARACTERISTICS

Function: FACTOR

Experiment Model Number 7:
One Factor Randomized Complete Block Design
Data case no. 1 to 50.

Factorial ANOVA for the factors:
Replication (Var 1: Rep) with values from 1 to 5
Factor A (Var 2: Treatment) with values from 1 to 10

Variable 3: SFM

Grand Mean = 11.797 Grand Sum = 589.860 Total Count = 50

T A B L E O F M E A N S

1	2	3	Total
1	*	11.061	110.610
2	*	10.242	102.420
3	*	12.743	127.430
4	*	14.376	143.760
5	*	10.564	105.640
*	1	4.206	21.030
*	2	14.646	73.230
*	3	14.942	74.710
*	4	19.526	97.630
*	5	19.964	99.820
*	6	4.966	24.830
*	7	5.880	29.400
*	8	5.848	29.240
*	9	12.646	63.230
*	10	15.348	76.740

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	**Prob**
1	Replication	4	120.262	30.065	1.3049	0.2867
2	Factor A	9	1662.314	184.702	8.0161	0.0000
-3	Error	36	829.486	23.041		
	Total	49	2612.062			

Coefficient of Variation: 40.69%

$s_{\bar{y}}$ for means group 1: 1.5179 Number of Observations: 10

$s_{\bar{y}}$ for means group 2: 2.1467 Number of Observations: 5

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Variable 4: RFM

Grand Mean = 3.357 Grand Sum = 167.830 Total Count = 50

T A B L E O F M E A N S

1	2	4	Total
1	*	2.225	22.250
2	*	2.960	29.600
3	*	3.806	38.060
4	*	5.463	54.630
5	*	2.329	23.290
*	1	1.742	8.710
*	2	3.480	17.400
*	3	5.756	28.780
*	4	6.348	31.740
*	5	7.216	36.080
*	6	2.104	10.520
*	7	0.768	3.840
*	8	0.582	2.910
*	9	1.458	7.290
*	10	4.112	20.560

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	71.327	17.832	5.4870	0.0015
2	Factor A	9	261.831	29.092	8.9521	0.0000
-3	Error	36	116.992	3.250		
	Total	49	450.150			

Coefficient of Variation: 53.71%

$s_{\bar{y}}$ for means group 1: 0.5701 Number of Observations: 10

$s_{\bar{y}}$ for means group 2: 0.8062 Number of Observations: 5

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Variable 5: SDM

Grand Mean = 4.392 Grand Sum = 219.580 Total Count = 50

T A B L E O F M E A N S

1	2	5	Total
1	*	4.257	42.570
2	*	4.369	43.690
3	*	4.370	43.700
4	*	4.738	47.380
5	*	4.224	42.240
*	1	1.610	8.050
*	2	5.148	25.740
*	3	5.322	26.610
*	4	6.834	34.170
*	5	6.352	31.760
*	6	2.252	11.260
*	7	2.476	12.380
*	8	2.746	13.730
*	9	5.692	28.460
*	10	5.484	27.420

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	1.672	0.418	0.1370	
2	Factor A	9	164.117	18.235	5.9759	0.0000
-3	Error	36	109.853	3.051		
	Total	49	275.642			

Coefficient of Variation: 39.78%

$s_{\bar{y}}$ for means group 1: 0.5524 Number of Observations: 10

$s_{\bar{y}}$ for means group 2: 0.7812 Number of Observations: 5

Variable 6: RDM

Grand Mean = 0.657 Grand Sum = 32.840 Total Count = 50

T A B L E O F M E A N S

1	2	6	Total
1	*	0.541	5.410
2	*	0.641	6.410
3	*	0.716	7.160
4	*	0.770	7.700
5	*	0.616	6.160
*	1	0.342	1.710
*	2	0.614	3.070
*	3	1.044	5.220
*	4	1.402	7.010
*	5	1.336	6.680
*	6	0.342	1.710
*	7	0.188	0.940
*	8	0.210	1.050
*	9	0.306	1.530
*	10	0.784	3.920

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.316	0.079	0.8754	
2	Factor A	9	9.626	1.070	11.8363	0.0000
-3	Error	36	3.253	0.090		
	Total	49	13.196			

Coefficient of Variation: 45.77%

$s_{\bar{y}}$ for means group 1: 0.0951 Number of Observations: 10

$s_{\bar{y}}$ for means group 2: 0.1344 Number of Observations: 5

Variable 7: RSR

Grand Mean = 0.196 Grand Sum = 9.822 Total Count = 50

T A B L E O F M E A N S

1	2	7	Total
1	*	0.111	1.106
2	*	0.173	1.733
3	*	0.179	1.793
4	*	0.303	3.026
5	*	0.216	2.164
*	1	0.209	1.047
*	2	0.145	0.724
*	3	0.195	0.976
*	4	0.409	2.045
*	5	0.239	1.196
*	6	0.132	0.659
*	7	0.067	0.335
*	8	0.073	0.367
*	9	0.052	0.260
*	10	0.443	2.213

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.199	0.050	0.8049	
2	Factor A	9	0.837	0.093	1.5069	0.1829
-3	Error	36	2.221	0.062		
	Total	49	3.257			

Coefficient of Variation: 126.45%

$s_{\bar{y}}$ for means group 1: 0.0786 Number of Observations: 10

$s_{\bar{y}}$ for means group 2: 0.1111 Number of Observations: 5

Variable 8: SMR

Grand Mean = 0.881   Grand Sum = 44.066   Total Count = 50

TABLE OF MEANS

1	2	8	Total
1	*	0.902	9.025
2	*	0.856	8.559
3	*	0.857	8.574
4	*	0.877	8.766
5	*	0.914	9.142
*	1	0.830	4.149
*	2	0.904	4.519
*	3	0.840	4.198
*	4	0.828	4.140
*	5	0.813	4.063
*	6	0.888	4.441
*	7	0.938	4.688
*	8	0.935	4.674
*	9	0.978	4.888
*	10	0.861	4.306

ANALYSIS OF VARIANCE TABLE

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.028	0.007	1.8245	0.1455
2	Factor A	9	0.141	0.016	4.1294	0.0010
-3	Error	36	0.137	0.004		
	Total	49	0.305			

Coefficient of Variation: 6.99%

$s_{\bar{y}}$ for means group 1: 0.0195   Number of Observations: 10

$s_{\bar{y}}$ for means group 2: 0.0276   Number of Observations: 5

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Variable 9: RMR

Grand Mean = 0.124   Grand Sum = 6.213   Total Count = 50

T A B L E   O F   M E A N S

1	2	9	Total
1	*	0.098	0.975
2	*	0.143	1.432
3	*	0.142	1.424
4	*	0.140	1.400
5	*	0.098	0.982
*	1	0.170	0.851
*	2	0.121	0.607
*	3	0.160	0.802
*	4	0.172	0.860
*	5	0.187	0.935
*	6	0.112	0.559
*	7	0.061	0.305
*	8	0.073	0.366
*	9	0.048	0.238
*	10	0.138	0.690

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
1	Replication	4	0.023	0.006	1.8211	0.1461
2	Factor A	9	0.112	0.012	3.9015	0.0016
-3	Error	36	0.115	0.003		
	Total	49	0.251			

Coefficient of Variation: 45.52%

$s_{\bar{y}}$ for means group 1:   0.0179   Number of Observations: 10

$s_{\bar{y}}$ for means group 2:   0.0253   Number of Observations: 5

APPENDIX-G

Percentage survival of *Artemisia afra* transplants in different media and various treatments

Treatment	Replication	No. which potted	No. of cuttings survived	% No. survived
Control + seedling mix	1	4	4	100
	2	4	4	100
	3	4	4	100
	4	4	4	100
	5	4	3	75
Total		**20**	**19**	**95**
Control + Soil	1	4	3	75
	2	4	3	75
	3	4	4	100
	4	4	2	50
	5	4	0	0
Total		**20**	**12**	**60**
Nitrogen 1/week + Seedling mix	1	4	3	75
	2	4	2	50
	3	4	3	75
	4	4	3	75
	5	4	0	0
Total		**20**	**11**	**55**
Nitrogen 1/week + Soil	1	4	0	0
	2	4	0	0
	3	4	3	75
	4	4	3	75
	5	4	3	75
Total		**20**	**9**	**45**
Nitrogen 3/week + Seedling mix	1	4	3	75
	2	4	4	100
	3	4	3	75
	4	4	3	75
	5	4	3	75
Total		**20**	**16**	**80**
Nitrogen 3/week + Soil	1	4	0	0
	2	4	4	100

Potting mix	Aqua fertilizer 1/week	1	4	4	100
		2	4	4	100
		3	4	4	100
		4	4	3	75
		5	4	4	100
Total			20	19	95
Soil	Aqua fertilizer 1/week	1	4	3	75
		2	4	1	25
		3	4	3	75
		4	4	0	0
		5	4	0	0
Total			20	7	35
Potting mix	Aqua fertilizer 3/week	1	4	3	75
		2	4	4	100
		3	4	3	75
		4	4	3	75
		5	4	4	100
Total			20	17	85
Soil	Aqua fertilizer 3/week	1	4	3	75
		2	4	3	75
		3	4	3	75
		4	4	3	75
		5	4	4	100
Total			20	16	80

APPENDIX-H

Root characteristics of *Artemisia afra* (African wormwood) cuttings treated with PBZ and IBA (Seradix no.1)

Treatment	Rep	No. Taken	Very good-good (No.)	% V.good – good	Very little or no rooting(No)	% V.little or no rooting
PBZ Alone	1	15	13	87	2	13
	2	15	11	73	4	27
	3	15	14	93	1	7
	4	15	11	73	4	27
Total		**60**	**49**	**82**	**11**	**18**
IBA Alone	1	15	15	100	0	0
	2	15	7	47	8	53
	3	15	12	80	3	20
	4	15	14	93	1	7
Total		**60**	**48**	**80**	**12**	**20**
PBZ +IBA	1	15	14	93	1	7
	2	15	9	60	6	40
	3	15	11	73	4	27
	4	15	13	87	2	13
Total		**60**	**47**	**78**	**13**	**22**
Control	1	15	11	73	4	27
	2	15	8	53	7	47
	3	15	9	60	6	40
	4	15	12	80	3	20
Total		**60**	**40**	**67**	**20**	**33**

APPENDIX-I

Visual rating of disease status on *Artemisia afra* cuttings treated with PBZ and IBA

Treatment	Rep	No.taken	Free	%	Minor Infections	%	Substantial Infections	%
PBZ Alone	1	15	8	53	6	40	1	7
	2	15	5	33	10	67	0	0
	3	15	6	40	9	60	0	0
	4	15	5	33	10	67	0	0
Total		**60**	**24**	**40**	**35**	**58**	**1**	**2**
IBA Alone	1	15	3	20	11	73	1	7
	2	15	3	20	11	73	1	7
	3	15	8	53	7	47	0	0
	4	15	7	47	8	53	0	0
Total		**60**	**21**	**35**	37	**62**	**2**	**3**
PBZ and IBA	1	15	8	53	7	47	0	0
	2	15	7	47	5	33	3	20
	3	15	11	73	4	27	0	0
	4	15	7	47	8	53	0	0
Total		**60**	**33**	**55**	**24**	**40**	**3**	**5**
Control	1	15	9	60	6	40	0	0
	2	15	5	33	9	60	1	7
	3	15	4	27	11	73	0	0
	4	15	3	20	12	80	0	0
Total		**60**	**21**	**35**	**38**	**63**	**1**	**2**