ROOTING TECHNIQUES FOR SELECTED TREE SPECIES

by

Charles Petrus Laubscher

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Study Leaders
Dr H de Lange
Ms C Joubert

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DECLARATION

I, the undersigned hereby declare that the work contained in this thesis is my own original work and has not previously in its entirety or in part been submitted at any tertiary educational institution for a diploma or degree. I do further declare that the opinions contained herein are my own and not necessarily those of the Cape Technikon.

Signature .... Date ....18. 10. 99....

SUMMARY

Vegetative propagation techniques for rooting of cuttings of indigenous tree species, i.e. Olea europaea subsp. africana, Podocarpus falcatus, Syzigium cordatum and introduced species, i.e. Acacia mearnsii, A. melanoxylon, Eucalyptus grandis and Melia azedarach were studied and improved at the Cape Technikon nursery from May 1994 to June 1998.

These tree species are considered problematic since the indigenous species produce unwanted fruits in urban areas which attract frugivores, while the introduced species are a threat to indigenous vegetation and natural habitats, though they are of great commercial value.

The progress in mutation breeding of sexual sterility in most of the problematic species created a need to propagate them vegetatively. Without cloning of seedless species, their beauty and economic value to South Africa will be lost, as the indigenous species will be neglected, while invasive species will continue to threaten the natural habitat of indigenous species.

Experiments were conducted to test age, type and length of cuttings, environmental factors, growth season, hormone application, various treatments and rooting media for each of these species. This study showed that relatively few publications relevant to the vegetative propagation of indigenous tree species are available. However, some introduced species, e.g. Eucalyptus grandis, are propagated successfully for commercial forestry purposes.

Ficus sur and Syzigium cordatum showed the highest rooting success, i.e. 85-90%, followed by Olea europaea subsp. africana (75-80%), and Podocarpus falcatus (60%). The introduced species showed no rooting success, however, callusing in Eucalyptus grandis (35-61%), and Melia azedarach (50%), and survival rates in Acacia mearnsii (10%) and A. melanoxylon (20%) were achieved. Treatments, i.e. etiolation, placing plants under stress, sealing basal stems of cuttings, and fungicide treatments all showed positive results in promoting callusing success. The study showed that rooting success in individual species are directly related to the growth stage of parent plants as well as the season during which the cuttings were taken.

With progress towards successful vegetative propagation of sterile problem plant species, propagators and horticulturists can in future apply these improved techniques. These plants will then continue to supply timber, fire wood and improve aesthetics in the South African urban environment.

OPSOMMING

Vegetatiewe voortplantingstegnieke vir die bewortelling van steggies van inheemse boomspesies, nl. Olea europaea subsp. africana, Podocarpus falcatus, Syzigium cordatum en uitheemse spesies, nl. Acacia mearnsii, A. melanoxylon, Eucalyptus grandis en Melia azedarach is vanaf Mei 1994 tot Junie 1998 by die Kaapse Technikon kwekery bestudeer en verbeter.

Hierdie boomspesies word as problematies beskou aangesien die inheemse spesies ongewenste vrugte in beboude gebiede produseer wat vrugte-eters lok, terwyl die uitheemse spesies 'n groot bedreiging vir die inheemse plantegroei en natuurlike habitatte inhou, alhoewel hulle ook groot kommersiële waarde het.

Die vooruitgang in mutasieteling vir geslagtelike steriliteit in die meeste van die probleemspesies het 'n behoefte om hulle vegetatief te kweek, teweeggebring. Sonder die kloning van saadlose spesies, sal hul prag en ekonomiese waarde vir Suid-Afrika verlore wees, aangesien die inheemse spesies verwaarloos sal word terwyl die indringerspesies sal voortgaan om die natuurlike habitatte van die inheemse spesies te bedreig.

Eksperimente is uitgevoer om die ouderdom, tipe en lengte van steggies, omgewingsfaktore, groeiseisoen, hormoonaanwending, verskillende behandelings en bewortelingsmedia vir elk van die spesies te toets. Hierdie studie het getoon dat relatief min publikasies ten opsigte van die vegetatiewe voortplanting van inheemse boomspesies

beskikbaar is. Sekere uitheemse spesies, bv. Eucalyptus grandis word egter vir kommersiële bosboudoeleindes reeds suksesvol voortgeplant.

Ficus sur en Syzigium cordatum het die hoogste bewortelingsukses, nl. 85-95% gelewer, gevolg deur Olea europaea subsp. africana (75-80%), en Podocarpus falcatus (60%). Die uitheemse spesies het geen bewortelingsukses getoon nie, alhoewel kalusvorming in Eucalyptus grandis (35-61%) en Melia azedarach (50%), en oorlewingsuksesse in Acacia mearnsii (10%) en A. melanoxylon (20%) verkry is. Behandelings, nl. etiolering, blootstelling aan stres, die seël van basaalstingels van steggies en swamdoderbehandelings het almal positiewe resultate in die bevordering van kallus gelewer. Die studie het getoon dat bewortelingsukses van individuele spesies direk verband hou met die groeistadium van die ouerplante asook die seisoen waarin die steggies geneem word.

Kwekers en tuinboukundiges kan met die ontwikkeling van suksesvolle vegetatiewe voortplantingstegnieke vir steriele probleemplantspesies, hierdie verbeterde tegnieke in die toekoms toepas. Hierdie plante kan dus bly voortbestaan om timmer- en vuurmaakhout te voorsien en die estetiese waarde van die Suid-Afrikaanse beboude omgewing te verbeter.

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INTRODUCTION

The urge for a greater diversity and variation in plant life, particularly useful to the welfare of mankind, led to the deliberate introduction of plant species from other countries into South Africa (Immelman et al., 1973). This idea was promoted by J. Bowie and Baron von Ludwig, both responsible for many plant introductions, and J.C. Brown, who encouraged the public throughout the Cape Colony to grow as many trees and shrubs as possible of any kind that would grow (Shaughnessy, 1980). However, many indigenous plant species have also become problematic in urban areas.

Plants in urban areas have to fulfil certain requirements, e.g. to qualify as street trees. For this reason selectivity has become a high priority and plant improvement would have little significance, without methods whereby improved forms could be maintained in cultivation. What remains constant with vegetative propagation, as this study will show, is that the genetic identity of the plant once selected will remain unchanged during vegetative propagation.

Although the economic and/or aesthetic values of the plant species selected for this study are important, these plant species also negatively affect the human environment in South Africa and are thus considered problem plants. Urgent research for plant improvement is required to ensure their continued use in South Africa. For the purpose of this study indigenous species, i.e. Olea europaea subsp. africana, Podocarpus falcatus, Syzigium cordatum, Ficus sur as well as introductions from Australia, i.e. Acacia mearnsii, A. melanoxylon, Eucalyptus grandis and from South America, i.e. Melia azedarach were used.

The first group of plants identified to be problematic are indigenous to South Africa. Podocarpus, Olea, Syzigium, and Ficus spp. have, amongst others, been used for ornamental street planting purposes in municipal areas or as garden specimens in public gardens or parks and form part of this study. These indigenous trees are used to soften the lines of the buildings and to create an aesthetic environment. The idea of planting indigenous trees, which would be climatically suitable to these areas, did not take in consideration some of the problems these trees could cause once established. They, however, have a high seed-output which attracts large numbers of fruit bats and birds which cause pollution and damage to buildings and cars. This has become a major problem for local authorities, e.g. fruit-eating bats feed throughout the year on seeds of Podocarpus falcatus and Olea europaea subsp. africana and defecate on the walls of buildings causing extensive non-removable staining and damage to paint work (Jacobs, 1996). During summer, the bats also feed on the fruit of Ficus sur, another popular tree for street planting, thus continuing the cycle throughout the year. Podocarpus spp. when in fruit, also attract large numbers of birds which have become a problem to local authorities.

Presently the only effective means of preventing the damage is to remove the fruit from the trees before they ripen. The cost of repainting buildings annually or the removal of the fruit from these plant species are prohibitive and necessitate alternative solutions.

The second group of problematic species identified for this study has all been introduced into South Africa. The earliest record of Australian tree species introduced into South Africa appears in a catalogue of the Botanic Gardens published during 1858 (Shaughnessy, 1980). This catalogue revealed that seeds of Acacia mearnsii were brought from England. Shaughnessy (1980) reported that the public was encouraged to convert the barren slopes of

Table Mountain into valuable forest land and to plant Australian species because they were well adapted to the climate of South Africa. This idea was initially romanticised by planting introduced plant species which would adapt to South African environmental conditions which are similar to those in their country of origin. In 1890 the forestry department of Cape Town engaged in a plan to establish plantations on the slopes of Table Mountain with an attempt to reduce the risk of fire on the mountain. Acacia mearnsii and A. melanoxylon are two of the species planted.

Today invasive species have transformed 42% of mountain fynbos (Richardson et al., 1992) while 750 indigenous species are being threatened by invasions. Introduced Acacia spp. are particularly robust growing and form invasive stands which pose a great threat to South Africa's floral heritage. They also have a high seed-output whereby they spread to uncontrollable numbers. Milton (1982) found that the nitrogen and phosphorus content of the leaves and bark of Australian Acacia spp. growing in the south-western Cape are two to four times greater than in fynbos plants. She suggests further that these species enrich the soil with nitrogen and phosphorus and therefore make the environment less suitable for fynbos species which are adapted to nutrient-poor soils.

Acacia melanoxylon was introduced to Cape Town around 1848 (Shaughnessy, 1980). From 1856 it was used extensively as forest replacement species in the Knysna forest. Immelman et al. (1973) reported that Acacia melanoxylon is a fast grower, but considered being a threat to the indigenous forests of South Africa. For a number of years, this species was propagated as ornamental plants, shade trees, and also for industrial purposes. During this time no serious thought was given to the rapid increasing numbers of this species. Acacia melanoxylon has a high seed germination success, i.e. 99-100% (De Zwaan, 1982). Seeds are easily spread by birds and can lie dormant for over a hundred years till fire and cultivation of soil may activate seed to germinate in large numbers (Coetsee, 1990). De Zwaan (1982) reported that Acacia melanoxylon thrives best in moist sites. This evidence alone gives reason to be concerned about the amount of water this species consumes along riverbanks and streams. With up to 16% protein in their young foliage, Acacia melanoxylon plants are a delectable food for browsing animals. Buck, cattle and also Knysna elephant consume substantial amounts of Acacia melanoxylon foliage (De Zwaan, 1982). It also provides shelter and shade to animals (Immelman et al., 1973), apart from yielding one of the finest cabinet and furniture woods grown in South Africa. Acacia melanoxylon has been rated as the third most invasive species in indigenous forests in South Africa (Richardson et al., 1992).

Acacia mearnsii was introduced mainly for cultivation in commercial plantations for its bark which was exported to England from 1886 (Shaughnessy, 1980). The bark of Acacia mearnsii contains more than 30% tannin which is used for tanning purposes (Donnelly, unpublished). The wood is mainly used as mining timber, building poles, hardboard, wood-chip and firewood (Immelman et al., 1973). These trees are also actively used by domestic animals, e.g. cattle and sheep for shelter and shade. Acacia mearnsii is drought and frost resistant and grows fast in almost any soil type. It grows particularly along rivers, streams and furrows mainly in high rainfall areas on deep, well-drained soils but establishes on shallower soils if there is sufficient water (Shaughnessy, 1980).

Acacia mearnsii ranks third in riverine invasions of South Africa (Richardson et al., 1992). It is also described as South Africa's most widespread and abundant weed (Donnelly, unpublished). Donnelly (1992) reported that Acacia mearnsii, on a national scale, has been implicated as the most problematic weed. Up to 60 000 seeds of Acacia mearnsii have been found per square metre in the soil beneath large trees (Donnelly, unpublished). Seeds of Acacia mearnsii are known to have a lifespan of more than 50 years (Shaughnessy, 1980). Soils supporting Acacia mearnsii were found to dry out rapidly after rain, and were desiccated to wilting point by the middle of winter (Beard, 1963). Advanced soil erosion was observed in river beds invaded by Acacia mearnsii, because the roots of this tree are shallow and are easily uprooted when water levels rise (Grindley, 1984).

Melia azedarach, a deciduous tree from the Western Himalayas, is suitable for furniture, cabinet work, panelling and also makes excellent firewood (Immelmann et al., 1973). Cultivated for shade and ornamental purposes in parks and gardens, this species is also suitable for street planting purposes. However, the seeds of Melia azedarach can cause poisoning and are not always favoured for use in public places where children can readily gain access to its fruits (Immelman et al., 1973). This species has spread to such an extend that it threatens indigenous habitats in national parks, e.g. Kruger National Park (Coates Palgrave, 1983). It has naturalized in subtropical areas of the Eastern Cape and has spread to invasive stands in KwaZulu-Natal and Gauteng (Shaughnessy, 1980).

Eucalyptus grandis grows fairly fast on most soils and is mainly used for construction work, furniture, joinery, panelling, flooring, box wood, shelter belts, telephone poles, mining timber, hardboard and rayon pulp (Esterhuyse, 1989). Eucalyptus grandis occurs naturally in the warm humid, coastal regions of central and northern New South Wales and southern Queensland, Australia. This species is practically immune to snout beetle (Melanterius spp.) attack and thrives on sandy and clayey soils if sufficiently moist and deep (Immelman et al., 1973). In Australia, especially, and elsewhere in the world, Eucalyptus spp. are used in agroforestry, for the multiple uses of the wood as well as their importance for honey production (Esterhuyse, 1989).

Because of their adaptability to a variety of soil and environmental conditions, Eucalyptus spp. have managed to escape to almost uncontrollable numbers in mountain catchment areas. Conservation management, control of land use, and the prevention of soil erosion are only a few measures to assist with the destruction of this intruding tree species and the protection of natural vegetation. The effect of Eucalyptus invasion on nutrient cycles and the energy balance are poorly understood. However, Adler (1985) reported that it is estimated that soil erosion in South Africa takes place at the alarming rate of 10 tons per person per year.

Some introduced tree species have spread to such an extend that biological control has been introduced to control them (Shaughnessy, 1980). Biological control of Australian Acacia spp. began in 1970 and was intensified from 1981 (Donnelly, 1992). The South African Plant Protection Research Institute has an active research programme on biological control of plant invaders. They are involved with the introduction of host-specific organisms such as insects, fungi, etc. which attack both the vegetative and reproductive systems of the invasive plants to reduce fruit/seed production to control the numbers of plants. The seed-feeding weevil Melanterius acaciae was released in 1985 to curb seed production of Acacia melanoxylon (Donnelly, unpublished). The introduction of the seed-feeding weevil Melanterius maculatus for the control of Acacia mearnsii was accepted in March 1992 after members of the wattle industry, strongly expressed the fear that seed-feeding insects released on Acacia spp. would hamper the natural re-establishment of wattle plantations after felling (Donnelly, 1992). Biocontrol programmes contribute mostly to the reduction in the rate of spread of invader species into new areas and can therefore be regarded as the only feasible long-term solution to control invasive plants (Donnelly, 1992). Chemicals are also used to eradicate plants or to prevent further spreading of invasive species. The use of herbicides in South Africa is strictly controlled and chemicals must be tested and registered for use against particular plant species before they can be recommended. Mechanical control has proved very costly due to the rising cost of labour in South Africa. However, the South African government has proceeded with a new project as part of the Reconstruction and Development Programme to use unemployed workers to remove invasive plants in mountain fynbos and other water catchment areas in South Africa.

Even though biological, chemical and mechanical methods are used to reduce the spread of these introduced species, their continued utilization is warranted because of their potential and present economic benefit to the horticultural, mining, furniture, timber and agricultural industries. These species also have a future in agroforestry whereby various plant species and livestock are integrated to support each other to provide multiple products from a single site (Esterhuyse, 1989). Systems which incorporate tree and shrub species are, e.g. A. melanoxylon which produces biomass and fodder and fix atmospheric nitrogen which are important for the decomposing of organic matter. Agroforestry systems are designed in such a way that they are sustainable in the long term having both economic and ecological benefits (Armstrong, 1992).

All the plant species used in this study are mainly self propagated by means of seed. Most of the seeds, e.g. Acacia spp. can survive for many years and germinate easily while many new hybrids and strains developed through interbreeding (De Zwaan, 1980). Offspring of some of these species, e.g. Acacia melanoxylon can be more hardy and tolerant to environmental conditions than individuals growing in their natural habitat, e.g. seeds become longer-lived and plants can survive drought conditions (Coetsee, 1990).

The main problem to overcome is the control of fruiting and seed set of the problematic indigenous and introduced species. Replacing problem trees in municipal areas with male or sterile trees is a long-term solution, but may also be the only solution if these species are continued to be used for ornamental purposes in South Africa. The control of introduced species will not only minimize invasion of the veld and release pressure on indigenous plant species, but also limit wastage of water resources and catchment areas in South Africa. Positive action must therefore be taken to control the damage caused and spread of these plants. The Argus (1993) reported that managers of commercial nurseries in greater Cape Town stock highly invasive alien plants for sale and are ignorant of certain environmental issues affecting indigenous vegetation. A survey found that Acacia melanoxylon, one of three species stocked at nurseries, are one of the 10 most invasive plants affecting fynbos. This report, however, was rejected by The Cape Association of Nurserymen as evidence revealed that participants taking part in the survey were requested tc stay anonymous.

The benefit for large scale production of sterile trees would be to select the plants with the best qualities, e.g. fast growing, no seed production and good quality wood. These plants are selected for a specific genotype and will be isolated as clones which can be perpetuated for mass production. Most of these species are difficult to reproduce vegetatively, either because of complex cell compositions or hormones which inhibit the initiation of root primordia.

Vegetative propagation has the advantage of mass production, uniformity of larger plants in a shorter time, propagating the exact replica of the parent plant, the cloning of plants with desirable characteristics (Beardsell, 1985) and ensuring that genetic purity is maintained (Hartmann et al., 1990). Excellent uniformity can be obtained with cuttings taken from one selected clone at a given age, having the same height and diameter. Such trees are much sought after, especially for wood production. Vegetative propagation also provides the opportunity for close matching of a selected clone to the special characteristics of a particular locality and is of great importance from a silvicultural point of view (Eldridge et al., 1994).

The question arises how these plants can continue to exist without causing problems or being invasive. The use of sterile plant material may be a solution. De Zwaan (1980) suggested three possible methods to develop sterile Acacia melanoxylon plants, e.g. to search for seedless trees among existing material, the artificial development of triploid trees by crossing cholchicin-induced tetraploids with normal diploids, and the development of sterile hybrids by other means. Studies are still under way to produce sterile plants which can be used for non-invasive, viable plantation purposes. Gamma-irradiation as a tool in mutation breeding may present a method whereby sterile genotypes could be bred. Such selections will have to be propagated vegetatively. Existing Acacia melanoxylon which either are male or have not produced seed during an observation period of at least three consecutive years can also be considered as a possibility of sterility (De Zwaan, 1980).

Once sterile plants have been isolated, they can be grown for commercial purposes. The only method of propagation of these selected plant species will be to propagate them vegetatively. During vegetative propagation, parts of the roots, stem or leaf of the plant are used to produce new plants. Being reproduced through mitosis, the new plants will be exact replicas of the sterile parent plant and will be genetically similar except in extremely rare cases of spontaneous mutations. Vegetative propagation includes cuttings, layering, budding and grafting.

De Zwaan (1982) stated that the development of a seedless A. melanoxylon requires high priority because the vegetative propagation of sterile trees would stop uncontrolled spreading of invasive plants and will protect the habitat of indigenous vegetation. Such a non-seed-bearing strain, propagated vegetatively, would be useful to the forest industry. De Zwaan (1982) revealed further that during collection of seed from selected trees it was observed that some trees often produce little or no seed. This raises the question why trees which yield little or no seed grow so well. Do they grow well because they are wholly or partly sterile? During the development and production of seed energy is needed, thus these almost seedless trees can use this un- or underutilised energy to improve their growing capacity (De Zwaan, 1982).

According to De Zwaan (1980), it is unlikely that sufficient hybrid or triploids will produce seed for commercial production. It is therefore a requisite that the plant material be propagated vegetatively. He also states that the added costs of vegetative propagation for commercial planting are justifiable in view of the high prices paid for, e.g. A. melanoxylon timber.

The use of different types of cuttings depend upon individual species. The season, age of the wood, and the growth stage of parent material were all considered in securing satisfactory rooting for the selected plants by De Zwaan (1980). Priority should be given to the most economic and most logical selection of the type of cutting. However, emphasis should be placed on studying the plant material closely to observe the growth and behaviour before deciding on an appropriate type of cutting for each individual plant species (Toogood, 1982). It is suggested (Lamb et al., 1975) that while the age of the parent plants may not matter so much in the case of easily rooted species, it becomes more important in those species which are more difficult to root, since the capacity for cuttings to generate roots tends to decrease with increasing age of the parent plant. Mother stock of older plants should be cut back and allowed to regenerate. Severely pruned plants, especially when young, tend to remain vegetative (Janick, 1986). Such plants draw on their carbohydrate reserve in the promotion of growth (Janick, 1986). The resulting low carbohydrate-nitrogen balance encourages vegetative growth. It is important when making softwood cuttings to obtain the proper type of cutting material from the stock plant. According to Hartmann et al. (1990) extremely fast-growing, soft tender shoots are not desirable, as they are likely to wilt and dry out before rooting.

It is recognized that sand acts as a stimulant to the cambium layer to produce roots (Gardiner, 1988). Titchmarsh (1993) recommends that coarse lime-free sand (1.5-2.5 mm in diameter) should be used for cuttings. It is important that sand, (1-3 mm in diameter) is fine enough to retain sufficient moisture, but also coarse enough to allow excess water to drain freely. The basic requirements of propagation mixtures should be a well-drained, open mixture with the capacity to retain moisture (Gardiner, 1988). Gardiner (1988) recommends that opinions differ on the ideal mix, however, a standard mixture of two parts of perlite, one part peat moss and two parts of washed sand should give good results. Including peat moss in a rooting medium considerably increases the mixture's water-holding capacity, and consequently the danger of over watering. High proportions of peat moss in the mixture if kept wet, can cause deterioration of the roots soon after they are formed. Peat moss has a high water-holding capacity and gives good aeration (Denisen, 1979). Selecting a suitable rooting medium for cuttings does not only influence the number of cuttings to be rooted but also the root mass and uniformity of the roots. For this reason emphasis has to be placed on testing various growth media as well as combinations of growth media to determine suitability for drainage and water holding capacity.

The bases of stem cuttings are wounded to release chemicals, in order to stimulate root production. Wounding exposes more young cells, increases the absorption rate of water, allows easier penetration of rooting hormones and removes barriers such as thick cell walls. Cutting material was also taken from selected parent plants which have shown variation in genotype constitution. Hartmann et al., (1990) suggested that root promoting treatments will not only increase the percentage of rooting for plants more difficult to root, but will also be beneficial with easily rooted plants. Rooting auxins can also increase the number and the quality of roots and promote uniformity in rooting. Indolebutyric acid (IBA) and naphthaleneacetic acid (NAA) have been found most reliable to stimulate adventitious rooting in cuttings (Hartmann et al., 1990). The most generally effective of these substances is indolebutyric acid while naththaleneacetic acid is effective on some species. Combinations of these chemicals give improved results (Lamb et al., 1975). Hartmann et al. (1990) found that it is also essential to root cuttings in conjunction with mist units, warm benches and cold frames to enhance quicker rooting. More uniform results are likely to be obtained under these conditions, because the absorption of the chemicals by the cuttings is not influenced as much by surrounding conditions as by the rooting powder (Lamb et al., 1975). Growth regulators, used in excessive concentrations, can inhibit bud development, cause yellowing and dropping of leaves, blackening of the stem or eventual death of the cuttings (Hartmann et al., 1990). Establishing and maintaining stable uniform environmental conditions are essential for rooting of the cuttings. Extreme fluctuations of these conditions can retard or inhibit rooting (Hartmann et al., 1990). Natural formation of roots is triggered by the accumulation of an optimum auxin level. Concentrations of auxin below the critical level are ineffective in root initiation, whereas those above that level can inhibit root growth and bud development (Janick, 1986). Hartmann et al. (1990) stated that treatment of cuttings with root-promoting substances is useful in propagating plants, however, the ultimate size and vigour of such treated plants is no greater than obtained with untreated plants.

Various degrees of success have been achieved with the vegetative propagation of these species, e.g. Olea europaea (Hartmann et al., 1990). However, many species and subspecies are still problematic.

Vegetative propagation is achieved by the induction of adventitious roots on stem cuttings, using the plant growth hormones, indole butyric acid (IBA) or indole acetic acid (IAA) (Glocke & Sedgley, 1995).

According to Glocke & Sedgley (1995) juvenile material of Acacia species are more likely to root than mature material and that cuttings should be taken from the lower, juvenile parts of the crown. Plants must be induced to shoot from the base by severe coppicing or pruning. Little is known of the internal changes which result in mature tissue being difficult to root and the length of the juvenile period which are influenced by environmental conditions, genetic factors and diseases, e.g. viruses. Hackett (1985) suggests that stock plants should be treated with plant regulators to retard growth resulting in an extended juvenile phase.

Lamb et al. (1975) suggest that nodal cuttings of Acacia species are taken from the current year's shoots in summer, treated with 0,8% IBA powder and inserted in a growth medium consisting of two parts of peat moss and one part of sand in a mist unit. De Zwaan (1980) reports that favourable results were obtained with root and stem cuttings, and from suitable young material. The main problems are the age of the material (e.g. success with material from trees with a trunk diameter of 100 cm or more has never been achieved) and the genotype constitution (some A. melanoxylon specimens, e.g. produce rooted cuttings with the greatest of ease, while others defy all attempts).

De Zwaan (1982) stated that in Tasmania Acacia melanoxylon grows in swamps which are inaccessible for nine months of the year. Stands in wet areas in South Africa, however, have given rise to high mortalities and sickly appearance of the survivors. For this reason he does not recommend their cultivation in wet areas. This factor must also be considered during rooting of A. melanoxylon, which can lead to deterioration and rotting of cuttings. Glocke & Sedgley (1995) also suggested that etiolation and girdling be used as techniques to aid vegetative propagation of this species.

Eucalyptus species are almost entirely propagated from seeds. However, according to Hartmann et al. (1990) 65% success with vegetative propagation has been obtained with Eucalyptus camaldulensis. Leafy cuttings were taken in early spring from shoots arising from the base of young trees. These shoots were wounded, treated with a 4000 ppm solution of a root-promoting mixture, 1 part indole butyric acid (IBA) to 1 part napthaleneacetic acid (NAA) and rooted in perlite under mist over bottom heat at 21°C. According to Hartmann et al. (1990) Eucalyptus ficifolia has also been successfully grafted by a side-wedge method, using young, vigourous Eucalyptus seedling rootstocks growing in containers and kept at a relative humidity of 70-80% following grafting. Scions taken from shoots which have been girdled, at least a month previously, showed increased success. He suggests further that this method of propagation will not be economically viable for production on a large scale, e.g. in forestry.

During the early 1960s Eucalyptus grandis was successfully raised from cuttings in Zambia, Brazil and Zaire (Christensen, 1973). According to Van Wyk (1977) only cuttings taken from coppice shoots during summer were successful. The success rate of these cuttings was too low to ensure viable commercial propagation of cuttings. Further experimentation resorted to the use of grafting methods. Cuttings taken from parent stock which have been ringbarked or from shoots which developed from coppiced young Eucalyptus grandis, however, have been raised successfully for mass vegetative purposes (Eldridge et al., 1994). These were prepared by cutting single nodes or two nodes when internodes were short. The tip of the cutting was removed and four to eight leaves were left on the cutting and then dipped into a fungicide (60% Benlate solution). Hormone treatment involves the use of 1-3% indolebutyric acid (IBA). Cuttings were individually planted preferably into single containers in combinations of mixtures consisting of milled bark, sand, sawdust, peat, vermiculite, perlite, and loam and raised in a greenhouse with stable temperature control at 20-24°C. Cuttings may be slow in rooting or may not root at all. However, chemical inhibitors found in, e.g. Eucalyptus grandis can retard the formation of roots (Paton et al., 1970).

Van Wyk (1977) reported that in 1962 the J.D.M. Keet Research station in Sabie (South Africa) investigated the vegetative reproduction of Eucalyptus species. Several attempts at rooting cuttings taken from coppiced shoots during summer failed, rendering the success rate of no practical value. Eldridge et al. (1994) reported that Eucalyptus grandis cuttings were raised successfully in nurseries in New South Wales, Australia, but that less than one hectare of plantation was established. In summer cuttings were raised from young coppiced shoots on felled trees, three to seven years old, as well as from plants growing in containers which were cut back on a regular basis. The cuttings were rooted in vermiculite under mist spray in shade covered beds under plastic. Cuttings are becoming increasingly popular for plantation use, e.g. by the mid-1980s more than one million cuttings were made of E. grandis annually in South Africa (Eldridge et al., 1994).

Ficus species can be propagated vegetatively by using existing vegetative propagation techniques (Hartmann et al., 1990), though very little information on the vegetative propagation of different Ficus species has been recorded so far. Cuttings of Ficus carica are best taken from hardwood parent plants, two to three years old, or from basal parts of vigorous one year old shoots (Hartmann et al., 1990). However, this type of cutting material cannot be considered viable for large scale economic production.

Since 1952 extensive studies by Hartmann et al. (1990) on the vegetative propagation of Olea species have been recorded. Although two-year-old hardwood cuttings are most often used in the propagation of deciduous woody species, some broad-leaved evergreens such as Olea species can be propagated by leafless hardwood cuttings (Hartmann et al., 1990). Narrow-leaved evergreen cuttings ordinarily were best taken between late autumn and late winter. Cuttings of Olea species can be rooted under mist if treated with IBA at 2000 ppm or they can be grafted on easily rooted cultivars used as rootstock. All leaves were removed from hardwood cuttings, basal ends were dipped in a 15 ppm IBA solution for 24 hours and stored in moist sawdust at 15-21°C for a month before planting them out in spring. Two-year-old wood can also be used for Olea species (Hartmann et al., 1990). Mallet stem cuttings can be treated for 4-5 seconds in a 4000 ppm IBA solution. Cuttings should be at least 6 mm in diameter and 100-150 mm long with two to six leaves. Cuttings will respond better from early to mid-summer plantings under a relative humidity of 70-80% provided by intermist spray and bottom heat (Hartmann et al., 1990).

Podocarpus falcatus can be propagated by stem cuttings taken in late summer (Hartmann et al., 1990). Very little information on the vegetative propagation of Podocarpus spp. have been recorded so far.

Future vegetative reproduction of both indigenous and introduced species is necessary to meet the demand for timber, firewood, ornamental purposes and urban landscaping. The only way these species can continue supplying industries with resources will depend on public awareness of conservation and the responsibility of authorities to reproduce sterile material vegetatively on a large scale in order to supply forest plantations, farmers and local authorities.

Planting of indigenous trees in urban areas should continue and the public should be encouraged to plant these trees, because they require less watering, no additional nutrients and are more adaptable to existing climatic and soil conditions than introduced species (Donald, 1991).

Armstrong (1992) stated that many of the introduced plant species are required for daily sustenance in South Africa and if their numbers would be completely reduced, only the original indigenous people who populated South Africa would be able to survive in a sustainable manner. Introduced plant species provide food, shelter and commercial products which sustain the future existence of these plant species. There is no doubt that these species are useful and that people will continue to plant them. Proper management of plant propagation is commendable to prevent these species from escaping into natural areas and threatening indigenous species and vegetation.

Forests are growing assets to humans and the hallmark of civilization is wise use and re-use of natural resources, not the exploitation, no matter how scientific and sophisticated exploitation may seem (Immelman et al., 1973).

Today most plants cultivated are propagated under controlled conditions which preserve the unique characteristics which make them useful. The development of knowledge and techniques to preserve plants must be considered, as progress in propagation techniques have developed, and the number of species which become available for cultivation increases. Improved methods of propagation must be found to retain the useful characteristics of these species.

A large percentage of propagation methods for some plant species have never been recorded with the result that limited guidelines are available to the grower on how to propagate these plants vegetatively (De Zwaan, 1980). Once sterile plants are developed, they can be isolated as clones and propagated vegetatively for their characteristics.

This study aims to investigate suitable vegetative propagation methods which would be economically viable for large scale production of sterile plants to ensure the continued use and existence of current problem species in South Africa such as Olea europaea subsp. africana, Podocarpus falcatus, Syzigium cordatum, Ficus sur, Acacia mearnsii, A. melanoxylon, Eucalyptus grandis and Melia azedarach. The objectives of this study are:

a) to record propagation methods being used in the trade,

b) to improve existing propagation methods,

c) to source new methods of vegetative propagation and

d) to be able to assist the industry in the growing of sterile plant material.

CHAPTER 1

MATERIALS AND METHODS

SELECTION OF PLANT MATERIAL

Plant material was collected from plants growing in the winter rainfall region of the Western Cape. Cuttings were selected as a method of vegetative propagation for the selected plants in order to retain the identity of the parent plant. Acacia and Eucalyptus cuttings were collected from invasive stands growing on mountainous terrain and in river beds, while cutting material for Olea europaea subsp. africana, Podocarpus falcatus, Syzigium cordatum, Ficus sur and Melia azedarach was collected from municipal areas in and around Cape Town where they are planted as street trees or garden specimens. All plant material was collected from fertile stock plants which are currently producing seed, as sterile plants were not available for this study.

AGE OF PLANT MATERIAL

Parent plant material selected for vegetative propagation was free of insects, disease symptoms, true to identity and was taken form young, moderately vigorous growing stock plants (Lamb et al., 1975). In the case of both Acacia mearnsii and A. melanoxylon cuttings were collected from young shoots, and also from water sprouts which originated on older wood (Poincelot, 1980). Eucalyptus grandis cuttings were collected from young shoots which developed on coppiced stems of three to four year old trees (Janick, 1986). For this study apical cuttings of Ficus sur were collected from trees 3-5 m tall, whereas similar, but woodier cuttings were collected from mature trees of Melia azedarach. Young juvenile wood was used for the vegetative propagation of Olea europaea subsp. africana. Young apical and stem cuttings of Syzigium cordatum were collected from two to three-year-old nursery trees which were well nourished, healthy and moderately vigorous growing.

METHODS OF PROPAGATION

Vegetative propagation by means of cuttings was selected as a first option as it is the most economical and easiest method of propagation. Cuttings were preferred, because they were easier to collect than seed, more abundant, survived better in transplanting, and collection did not harm the trees (Hartmann et al., 1990). Stem cuttings were chosen from hardwood, semi-hardwood and softwood.

Softwood cuttings were prepared from soft, succulent, new growth of deciduous and evergreen species. Some of their leaves were retained and kept in moist, cool conditions to prevent desiccation. Cutting material was selected for its flexibility, though mature enough to break when bent. The material was collected from lateral branches of the stock plants growing in full sunlight. The main shoots of the stock plants were cut back to force lateral shoots. Weak, thin, and vigorous, abnormally thick shoots were avoided. Softwood cuttings, 50-150 mm long, with two or more nodes were prepared. Basal cuts were made just below a node and the leaves of the lower portion of the cutting were removed. Leaves were reduced in size to lower the transpiration rate and to save space in the propagation bed (Toogood, 1982).

Hardwood stem cuttings were considered for deciduous and semi-deciduous species, e.g. Melia azedarach, because of their simplicity and low cost. Cuttings which contained lateral or terminal buds were obtained. The propagation material ranged from 250-300 mm and was taken from healthy, moderately vigorous stock plants growing in full sunlight. Harder wood of moderate size and vigour was found the most desirable. The wood selected did not have abnormally long or short internodes and were not from weak plants. Cuttings showed an ample supply of stored foods which could nourish the developing roots and shoots, until new plants became self-sustaining (Janick, 1986).

Tip growth of very young shoots were discarded while central and basal parts of young vigorous plants were selected for the best cuttings. At least two nodes were included for stem cuttings with a basal cut made just below a node. With some of the more fibrous species, e.g. Acacia mearnsii it was expected that rotting might occur much quicker, which could affect the survival of the cuttings. The diameter of the cuttings ranged from 5-15 mm. Polarity was maintained wherever stem cuttings were used. Mallet cuttings were made to include a short section of the stem of older wood. This method was selected because older wood has a stronger capacity to initiate root development, however, two-year-old and older wood can be used for Ficus and Olea spp. (Hartmann et al., 1990). Semi-hardwood cuttings were used for woody, broad-leaved evergreen species, e.g. Olea europaea subsp. africana.

Leafy softwood cuttings were taken from partially matured wood of Acacia mearnsii. Hartmann et al. (1990) advise that Olea species can be propagated by semi-hardwood cuttings. The cuttings were reduced to 100-250 mm with two to four leaves retained at the upper end.

Root cuttings were used for both Acacia species where little or no success could be achieved with stem cuttings. The root cuttings were inserted vertically with the top of the cutting at about soil level. This method maintains polarity and thus prevents cuttings from being planted upside down (Hartmann et al., 1990). Smaller root cuttings were cut 10-20 mm long, planted horizontally and covered 10-20 mm deep with a rooting medium. The root size of the plant determined the best procedure. Cuttings were placed in a shaded area and kept moist at all times.

Experiments for the present study were calculated at 40-50 cuttings x treatment x species = average rooting percentage. See Tables 1.1, 1.2, 1.3, 1.4, 1.6, 1.7, 1.10 and 1.12. This percentage was used to determine various factors which were tested using a follow up randomised block design, (Dehgan et al., 1994) calculated as follows: 90 cuttings x 10 treatments x 9 replications (total 900 cuttings per species) = percentage rooting. See Tables 1.5, 1.8, 1.9, 1.11 and 1.13.

GROWTH SEASON

Cutting material was collected throughout the year in order to test the suitability of the growth period. Softer wood cuttings were mainly prepared during the growth season for broadleaved evergreen species, e.g. Podocarpus falcatus, Olea europaea subsp. africana, Syzigium cordatum and during the growth season for deciduous species, i.e. Melia azedarach. Deciduous cuttings were mainly taken during autumn and winter from deciduous species, i.e. Melia azedarach. Stem and tip cuttings of Acacia mearsii and A. melanoxylon were mainly prepared in spring and summer, whereas root cuttings of both Acacia species were taken in late winter and early spring when the roots were well supplied with nutrients, but before new growth started (Glocke & Sedgley, 1995).

The hardwood deciduous cuttings (e.g. Melia azedarach) were prepared during the dormant season, i.e. late autumn, winter, and early spring from wood of the previous season's growth. Softwood tip cuttings were also prepared in summer from young seedlings.

The growth season to strike cuttings was determined also by the size of the cuttings. Smaller cuttings were considered earlier in the growth season because the juvenile shoots are more vigorous in growth (Janick, 1986). For this reason emphasis was placed on inducing rooting during specific stages of annual growth and development of Olea europaea subsp. africana.

Hardwood, evergreen cuttings of Podocarpus falcatus were prepared during autumn, however, cuttings were also taken from young seedling stock plants in early and mid-summer. This was done because younger growth contains more vigour which can root more readily than those taken from older trees (Hackett, 1985).

Cuttings of Syzigium cordatum were initially taken in spring and summer from new shoots just after a growth flush. Although the wood was only partially matured, it was too early to take cuttings. Young vigorous shoots were consequently taken later in the season.

TREATMENT

Several methods were used for preparing and handling cuttings before planting. Cuttings were collected and transported in plastic bags during the cool, early part of the day when the stems were turgid.

All propagation operations were conducted under relatively sterile conditions to prevent distribution of harmful organisms. Cutting material, containers, tools and surfaces were washed before cuttings were prepared. The plant material was kept in water to stay fresh while the cuttings were being prepared.

Wounding was done by a vertical cut (20 mm long), to expose the underlying cambium tissue on the lower sides of the stem. In order to prevent fungal infection, cuttings were soaked for a few seconds to ten minutes in a mild fungicide (Captan 5 g to 5 litres (0,1%) of water or Benlate 6 g to 10 litres (0,06%) of water to inhibit the development of fungi (Eldridge et al., 1994). The cuttings were then allowed to drain. Following this, the cuttings were treated with a root-promoting hormone just before they were planted in the propagation medium.

Cuttings of Acacia mearnsii and Olea europaea subsp. africana (Tables 1.1 and 1.7) were refrigerated at 10°C for two to three weeks, while Acacia melanoxylon (Table 1.2) was treated with hot water (80°C) for a few seconds to seal the exposed wound from deterioration (Hartmann et al., 1990). Cuttings were also soaked with basal ends in nutrients for 24 hours to encourage new growth and root initiation (Wright, 1973). All cuttings were treated with rooting hormones and growth regulators, particularly indole butyric acid (IBA) at different concentrations to improve root formation (Janick, 1986). "Seradix" powders Nos. 1, 2 and 3 contain 1 g/kg, 3 g/kg and 8 g/kg IBA respectively.

Hardwood cuttings were treated with more concentrated (0,8%), and tender, softer material was treated with less concentrated (0,2%) IBA. Excess powder adhering to the cuttings was removed to prevent a concentration of hormones. Only small amounts (10 g) of powder were used to dip cuttings in. Leftover powder was discarded after use to prevent using powder which could be contaminated with moisture, fungi or bacteria. Trenches and holes were made into the rooting medium to prevent the displacement of powder on the cuttings during insertion into the rooting medium (Hartmann et al., 1990).

Concentrated dip solutions were also used for experiments. See Tables 1.2, 1.3, 1.6, 1.7 and 1.10. These solutions varied from 2000 to 8000 ppm (0,2-0,8%) of a growth hormone in 50% alcohol (Hartmann et al., 1990). The basal ends of the cuttings were dipped in the solution for about five seconds before being inserted into the rooting medium. The same solutions were re-used, however, it was tightly sealed when not in use, as evaporation of the alcohol can change its concentration (Hartmann et al., 1990).

GROWTH MEDIUM

Soil, ordinarily used for planting deciduous hardwood and root cuttings, was excluded from the study because of the possibility of nematode, verticillium and grown gall infection. Titchmarsh (1993) recommends one part of peat moss and one part of coarse sand as a rooting medium. A widely used rooting medium, i.e. sand was used for cuttings, because it is a natural medium, sterile and more readily available.

Peat moss was mainly added to sand to increase the water-holding capacity of the mixture. Soil mixtures used, varied from 1:1 sand/peat moss to equal parts of sand, peat moss, polystyrene, vermiculite or bark (Gardiner, 1988). Polystyrene was used in mixtures to aerate the rooting medium. Vermiculite (grade 3) was used with mixtures of equal parts of peat moss and/or river sand (Mason, 1994). Water was also used as a rooting medium (Denisen, 1979).

ENVIRONMENT

To ensure successful rooting of the cuttings, environmental requirements were maintained in a greenhouse which received relatively high light intensities throughout the year. Light intensity was measured between 600-700 nm, while day and night temperatures were maintained at 20 and 28°C respectively with an average relative humidity of 70% to ensure atmospheric conditions conducive to low water loss from the plant material. Cuttings were rooted in greenhouse benches with automatic intermittent mist and thermostat controlled electric heating cables. Mainly softwood cuttings were rooted under conditions of high humidity or very light misting, to prevent excessive water loss, but without heavy wetting of the leaves. Temperatures in the hotbed were maintained at 21-23°C during rooting. Intermittent spray was used to cool down the surrounding atmosphere in the greenhouse. Where no bottom heat was required, cuttings were rooted in trays filled with growth medium. These trays were placed in the greenhouse and they all received uniform temperature of 24-28°C and humidity control at 70%.

Propagation experiments

Acacia mearnsii and A. melanoxylon

In autumn terminal, semi-hardwood cuttings were prepared for Australian Acacia spp. This method was used for Acacia baileyana, A. imbricata, A. glaucoptera, A. podalyriifolia, A. polybotrya and A. vestita, and can therefore be considered as a guideline for Acacia mearnsii and/or A. melanoxylon (Glocke & Sedgley, 1995). Cuttings were 120 mm long and the leaf area was reduced to one third. The cuttings were dipped into 1,25% bleach solution, treated for five seconds in 10 000 ppm IBA and planted in 1:1:1 mixture of sand, peat and perlite. Cuttings were then propagated under mist with bottom heat.

The length of cuttings (Table 1.1) was determined by the type of cutting which was used for this study. Thickness of stem cuttings ranged from 5-10 mm. Root cuttings were taken in early summer to allow new shoots to develop in the growth season. Wounding was done by a straight cut in most instances or for excessive wounding by scraping the bark to expose various layers of cambium tissue. Cuttings were treated (Table 1.1) to initiate rooting and to retard deterioration. Although various combinations of rooting media (Tables 1.1 and 1.2) were tested on Acacia mearnsii and A. melanoxylon, emphasis was placed on using coarse river sand as a rooting medium to allow for maximum drainage. Stems of some stock plants were also girdled to allow the accumulation of nutrients to enhance rooting.

Table 1.1 Propagation methods, hormone treatments and rooting media used for A. mearnsii in a controlled greenhouse at 24-28°C and 10 sec./18 min. misting irrigation. (n = 45).

Type of cutting	Age of cutting	Length of cutting (mm)	Bottom heat	Hormone treatment	Rooting medium
stem	semi-hardwood	250	no	No.2 IBA powder	1:1:1 bark sand polystyrene
terminal	softwood	150	no	No.1 IBA powder	1:1:1 bark sand polystyrene
stem	semi-hardwood	250	no	No.2 IBA powder	1:1 bark sand
terminal	softwood	150	no	No.1 IBA powder	1:1 bark sand
stem	semi-hardwood	250	no	No.2 IBA powder	sand
terminal	softwood	150	no	No.1 IBA powder	sand
stem	semi-hardwood	250	no	No.2 IBA powder	1:1 peat polystyrene
terminal	softwood	150	no	No.1 IBA powder	1:1 peat polystyrene
stem	semi-hardwood	250	no	No.2 IBA powder	bark
terminal	softwood	150	no	No.1 IBA powder	bark
terminal	softwood	150	no	refrigerated (10°C) callusing	sand
stem	hardwood	250-300	no	refrigerated (10°C) callusing	sand
stem	hardwood	250-300	no	excessive wounding refrigerated (10°C) callusing	sand
terminal	taken from girdled tree	150	no	No.2 IBA powder	sand
stem	semi-hard tip removed	150	no	No.2 IBA powder excessive wounding	sand
stem	semi-hardwood	100-200	yes	No.2 IBA powder	sand
terminal	softwood	100-200	yes	No.2 IBA powder	sand
stem (mallet)	softwood	150	yes	No.2 IBA powder	sand
terminal	softwood	100	yes	No.1 IBA powder	sand
stem (½ mallet)	softwood	100-150	yes	No.1 IBA powder	sand

Table 1.2 Propagation methods, hormone treatments and rooting media used for A. melanoxylon in a controlled greenhouse at 24-28°C and 10 sec./18 min. misting irrigation. (n = 45).

Type of cutting	Age of wood	Length of cutting (mm)	Bottom heat	Hormone treatment	Rooting medium
stem	semi-hardwood	250-300	Greenhouse misting	IBA 8000 ppm	sand
stem	semi-hardwood	250-300	Greenhouse misting	Refrigerated 0°C/24 hrs. IBA 8000 ppm 5 sec.	sand
stem	semi-hardwood	250-300	Greenhouse misting	10°C/24 hrs. IBA 8000 ppm 5 sec.	sand
stem	semi-hardwood	250-300	Greenhouse misting	basal cut soaked in saltwater 5g/l for 24 hrs. IBA 8000 ppm	sand
stem	semi-hardwood	250-300	Greenhouse misting	dipped in boiling water for 60 sec. IBA 8000 ppm	sand
stem 15 mm diameter	semi-hardwood	300-400	Greenhouse misting	IBA 4000 ppm	sand
stem 15 mm diameter	semi-hardwood	300-400	Greenhouse misting	diluted Kelp/5 min.	sand
stem 15 mm diameter	semi-hardwood	300-400	Greenhouse misting	No. 2 IBA powder	sand
stem 15 mm diameter	semi-hardwood	300-400	Greenhouse misting	No. 3 IBA powder	sand
terminal	softwood	100-150	hot bed/ misting	No.1 IBA powder	sand
terminal	softwood	100-150	Greenhouse misting	No.1 IBA powder	bark
terminal	softwood	100-150	Greenhouse misting	No.1 IBA powder	1:1:1 sand bark polystyrene
root	softwood	100-200	Greenhouse misting	none	sand

Eucalyptus grandis

Vegetative propagation of Eucalyptus grandis was performed with semi-hardwood stem cuttings from young vigorous growing trees. Cuttings were at least two internodes long with two to four leaves each. The leaves were trimmed to limit transpiration (Hartmann et al., 1990). The tender, soft shoot tips were removed to prevent the risk of further weakening of the cuttings. All cuttings were dipped into a fungicide bath (0,15% Benlate solution) for 25 seconds. This fungicide treatment was continued, similar to that for the Acacia species, by watering the cuttings on a weekly basis to prevent disease infection (Eldridge et al., 1994). Cuttings were then treated with 4000-8000 ppm IBA and planted in river sand and/or bark under mist spray. All the cuttings were placed in a greenhouse controlled environment with temperatures ranging from 24-28°C. See Table 1.3.

Table 1.3 Propagation methods, hormone treatments and rooting media used for E. grandis in a controlled greenhouse at 24-28°C and 10 sec./18 min. misting irrigation. (n = 50).

Type of cutting	Age of wood (years)	Length of cutting (mm)	Bottom heat	Hormone treatment	Rooting medium
stem	2-3	250-300	no	8000 ppm IBA	river sand
stem	2-3	250-300	no	4000 ppm IBA	river sand
stem	2-3	250-300	no	8000 ppm IBA	1 bark: 1 river sand
stem	2-3	250-300	no	4000 ppm IBA	1 bark: 1 river sand

Ficus sur

Personal observation of new growth indicated that late autumn/early spring is a favourable time to prepare nodal, internodal, and mallet cuttings of Ficus sur. Semi-hardwood cuttings, not shorter than 60 mm, were taken from vigorous growing stock plants. Cuttings were inserted into a rooting medium and placed in a temperature controlled greenhouse, either on a hot bed or on a gravel floor. Aeration in the rooting medium was considered important, however, the medium also had to retain sufficient moisture to prevent the cuttings from drying out.

Emphasis was placed on testing various combinations of rooting media. Intermittent irrigation was used to keep leaf surfaces moist during the rooting period. See Table 1.4.

Table 1.4 Propagation methods, hormone treatments and rooting media used on semi-hardwood cuttings of Ficus sur in a controlled greenhouse at 24-28°C and 10 sec./18 min. misting irrigation. (n = 45).

Type of cutting	Length of cutting (mm)	Bottom heat	Hormone treatment	Rooting medium
stem / nodal	60-120	yes	No.2 IBA powder	1:1 peat polystyrene
stem / internodal	60-120	yes	No.1 IBA powder	1:1 peat polystyrene
stem / heel	60-120	yes	No.3 IBA powder	1:1 peat polystyrene
stem / nodal	120-180	yes	No.2 IBA powder	river sand
stem / internodal	120-180	yes	No.1 IBA powder	river sand
stem /mallet	120-180	yes	No.3 IBA powder	river sand
stem / nodal	60	yes	No.2 IBA powder	river sand
stem / internodal	60	yes	No.1 IBA powder	river sand
stem/ heel	60	yes	No.3 IBA powder	river sand
½ mallet / shoot tip removed	60-120	no	No.2 IBA powder	1:1:1 peat sand vermiculite
½ mallet / shoot tip removed	60-120	no	No.3 IBA powder	1:1:1 peat sand vermiculite
½ mallet / shoot tip removed	60-120	no	No.1 IBA powder	1:1:1 peat sand vermiculite

A randomised block design for Ficus sur depicting length of cuttings, number of leaves and growing conditions was performed in a controlled greenhouse at 24-28°C and 10 sec./18 min.

misting irrigation. Half mallet cuttings were all treated with No.3 IBA powder and grown in 1 peatmoss : 1 polystyrene rooting mixture (Table 1.5).

Table 1.5 Randomized block design to compare length of cuttings, number of leaves and bottom heat/no heat treatments for Ficus sur. (n = 90).

Length of cutting (mm)	Number of leaves	Bottom heat
120-180	0	yes
60-120	0	yes
60	0	yes
120-180	2	yes
60-120	2	yes
60	2	yes
120-180	0	no
60-120	0	no
60	0	no
120-180	2	no
60-120	2	no
60	2	no
120-180	2-4	yes
60-10	2-4	yes
60	2-4	yes
120-180	2-4	no
60-120	2-4	no
60	2-4	no

Melia azedarach

Cuttings of Melia azedarach were prepared during late autumn, winter, and early spring from wood of the previous season's growth. Deciduous hardwood cuttings were prepared during the dormant period while leafy softwood cuttings (5-20 mm in diameter) were taken in mid-summer and inserted into sand on a heated bed under mist. All cuttings were inserted into the rooting medium, immediately after they were prepared to prevent wilting. See Table 1.6.

Table 1.6 Propagation methods, hormone treatments and rooting media used for Melia azedarach in a controlled greenhouse at 24-28°C and 10 sec./18 min. misting irrigation. (n = 45).

Type of cutting	Age of wood	Length of cutting (mm)	Bottom heat	Hormone treatment	Rooting medium
stem with tip	hardwood	200-250	no	No.3 IBA powder (glue)	river sand
stem with tip	hardwood	200-250	no	8000 ppm IBA	river sand
stem with tip	hardwood	200-250	no	4000 ppm IBA (hotwater)	river sand
stem	hardwood	200-300	no	No.3 IBA powder	river sand
stem	hardwood	200-300	no	8000 ppm IBA	river sand
stem	hardwood	200-300	no	4000 ppm IBA	river sand
stem with tip	hardwood	200-250	no	No.3 IBA powder	1:1 peat sand
stem with tip	hardwood	200-250	no	8000 ppm IBA	1:1 peat sand
stem with tip	hardwood	200-250	no	4000 ppm IBA	1:1 peat sand
stem	hardwood	200-300	no	No.3 IBA powder	1:1 peat sand
stem	hardwood	200-300	no	8000 ppm IBA	1:1 peat sand
stem	hardwood	200-300	no	4000 ppm IBA	1:1 peat sand
stem with tip	hardwood	200-250	no	No.3 IBA powder	1:1:1 sand bark polystyrene
stem with tip	hardwood	200-250	no	8000 ppm IBA	1:1:1 sand bark polystyrene

Table 1.6 continues

Type of cutting	Age of wood	Length of cutting (mm)	Bottom heat	Hormone treatment	Rooting medium
stem with tip	hardwood	200-250	no	4000 ppm IBA	1:1:1 sand bark polystyrene
stem	hardwood	200-300	no	No.3 IBA powder	1:1:1 sand bark polystyrene
stem	hardwood	200-300	no	8000ppm IBA	1:1:1 sand bark polystyrene
stem	hardwood	200-300	no	4000 ppm IBA	1:1:1 sand bark polystyrene
stem with tip	hardwood	200-250	no	No.3 IBA powder	1:1 peat polystyrene
stem with tip	hardwood	200-250	no	8000 ppm IBA	1:1 peat polystyrene
stem with tip	hardwood	200-250	no	4000 ppm IBA	1:1 peat polystyrene
stem	hardwood	200-300	no	No.3 IBA powder	1:1 peat polystyrene
stem	hardwood	200-300	no	8000 ppm IBA	1:1 peat polystyrene
stem	hardwood	200-300	no	4000 ppm IBA	1:1 peat polystyrene
stem with tip	hardwood	200-250	yes	No.3 IBA powder	river sand
stem with tip	hardwood	200-250	yes	8000 ppm IBA	river sand
stem with tip	hardwood	200-250	yes	4000 ppm IBA	river sand
terminal	softwood	50-100	yes	No.1 IBA powder	river sand
terminal	softwood	50-100	yes	No.1 IBA powder	river sand
terminal	softwood	50-100	yes	No.1 IBA powder	river sand

Olea europaea subsp. africana

In the preliminary experiments for this study, the propagation methods for Olea europaea subsp. africana recorded by Hartmann et al. (1990) were used as guidelines, and expanded to improve results. Emphasis was placed on using straight stem, heel, half-mallet, softwood, terminal cuttings from vigorous growing water shoots in older trees. Cuttings were collected throughout the year, however, emphasis was placed on the summer growing season. Cuttings were placed in various media, with coarse river sand (2-10 mm in diameter) for good drainage. Watering was supplied by mist irrigation (Table 1.7). All cuttings were treated with a fungicide, i.e. 0,15% Benlate and this treatment was continued on a weekly basis by watering the cuttings in the bed with the same solution to prevent fungal infection. Cuttings were monitored continuously for signs of rooting or callus formation. Mallet cuttings were preferred because of the large and older cambium layers which were exposed during wounding. Rooting hormones were used to increase the possibility of root initiation.

Table 1.7 Propagation methods, hormone treatments and rooting media used for Olea europaea subsp. africana in a controlled greenhouse at 24-28°C and 10 sec./18 min. misting irrigation and bottom heat in river sand. (n = 45).

Type of cutting	Age of wood (years)	Length of cutting (mm)	Hormone treatment
straight stem	1-2	100-300	No.2 IBA powder
heel	1-2	100-200	No.2 IBA powder
½ mallet	1-2	100-300	No.2 IBA powder
heel tip	2	70-120	No.2 IBA powder
½ mallet	2	100-300	No.2 IBA powder. 1-2 hrs. soaking
terminal	1-2	50	No.2 IBA powder / 1000 ml H_2O. 2 hrs. soaking
terminal	1-2	100-150	store at 10°C for 60 days
terminal	1-2	100-200	4000 ppm IBA
terminal	1-2	50-100	2000 ppm IBA
terminal	2	200-250	8000 ppm IBA

A randomised block design (Table 1.8) was used to compare the type, length, and diameter of cuttings, number of leaves, and the rooting medium on rooting success in Olea europaea subsp. africana in a controlled greenhouse at 24-28°C and 10 sec./18 min. misting irrigation. Cuttings were all treated with 4000 ppm IBA for five seconds, grown in coarse river sand (2-10 mm in diameter) with bottom heat (21-23°C).

Table 1.8 Randomized block design to compare type of cutting, number of leaves, distance from apex and diameter of cuttings on the rooting success in Olea europaea subsp. africana. (n = 90).

Type of cutting	No. of leaves	Distance from apex (mm)	Diameter of cutting (mm)
terminal	0	0-50	5
terminal	2	0-50	5
terminal	4	0-50	5
terminal	0	50-100	8
terminal	2	50-100	8
terminal	4	50-100	8
terminal	0	100-150	10
terminal	2	100-150	10
terminal	4	100-150	10
stem	0	50-100	10
stem	2	50-100	10
stem	4	50-100	10
stem	0	100-150	10
stem	2	100-150	10
stem	4	100-150	10
stem	0	150-200	10
stem	2	150-200	10
stem	4	150-200	10
mallet	0	50-100	10
mallet	2	50-100	10
mallet	4	50-100	10
mallet	0	100-150	10
mallet	2	100-150	10
mallet	4	100-150	10
mallet	0	150-200	10
mallet	2	150-200	10
mallet	4	150-200	10

Table 1.9 Rooting success in Olea europaea subsp. africana was studied by comparing type of cutting, number of leaves, distance from apex, diameter of cutting and rooting medium used. (n = 90).

Type of cutting	No. of leaves	Distance from apex (mm)	Diameter of cutting (mm)	Rooting medium
tip with mallet	2	100-150	8	1:1:1 peat sand polystyrene
tip with mallet	2	100-150	8	1:1:1 peat vermiculite polystyrene
tip with mallet	2	100-150	8	1:1 peat polystyrene
tip with mallet	2	100-150	8	river sand

Podocarpus falcatus

Propagation of Podocarpus falcatus was performed on soft tip cuttings after new growth has matured. Older wood was left on some cuttings when using mallet cuttings. Bottom heat with misting was used to increase the possibility of rooting. IBA powder and liquid concentrations (Table 1.10) were used as hormone applications on softwood and semi-hardwood cuttings.

Table 1.10 Propagation methods, hormone treatments and rooting media used for Podocarpus falcatus in a controlled greenhouse at 24-28°C and 10 sec./18 min. misting irrigation. (n = 45).

Type of cutting	**Age of wood**	**Length of cutting (mm)**	**Bottom heat**	**Hormone treatment**	**Rooting medium**
½ mallet with tip	semi-hardwood	150	no	No.2 IBA powder	bark
terminal	softwood	100	no	No.1 IBA powder	bark
½ mallet with tip	semi-hardwood	150	no	No.2 IBA powder	1:1 sand bark
½ mallet with tip	semi-hardwood	150	no	No.2 IBA powder	1:1:1 sand bark polystyrene
terminal	softwood	100	no	No.1 IBA powder	1:1:1 sand bark polystyrene
terminal	softwood	100	no	No.1 IBA powder	sand
½ mallet with tip	semi-hardwood	150	no	No.2 IBA powder	sand
terminal	softwood	100	no	No.1 IBA powder	sand
terminal	softwood	150	no	No.1 IBA powder	sand
terminal with mallet	semi-hardwood	150	no	No.1 IBA powder	sand
stem	semi-hardwood	150	no	No.2 IBA powder	sand
tip/stem	semi-hardwood	100-150	yes	8000 ppm IBA	sand
tip/stem	semi-hardwood	100-150	yes	4000 ppm IBA	sand
tip/stem	semi-hardwood	100-150	yes	2000 ppm IBA	sand
tip/stem	semi-hardwood	100-150	yes	1000 ppm IBA	sand
stem tip ½ mallet	softwood	100-150	no	No.1 IBA powder	1:1 peat polystyrene
terminal	softwood	100-150	no	No.1 IBA powder	1:1 peat polystyrene
stem tip ½ mallet	softwood	100-150	no	No.2 IBA powder	sand

A randomised block design was used to study the influence of the type and length of cuttings and the number of leaves on the rooting success of Podocarpus falcatus in a controlled greenhouse at 24-28°C and 10 sec./18 min. misting irrigation. Cuttings were all treated with No. 2 IBA powder and planted in coarse river sand (2-10 mm in diameter) with bottom heat (21-23°C). See Table 1.11.

Table 1.11 Randomized block design to compare type and length of cuttings, and number of leaves on the rooting success in terminal and stem cuttings of Podocarpus falcatus. (n = 90)

Type of cutting	Length of cutting (mm)	Number of leaves
terminal	100-150	2-6
stem	100-150	2-6
terminal	150-200	2-6
stem	150-200	2-6
terminal	100-150	none
stem	100-150	none
terminal	150-200	none
stem	150-200	none

Syzigium cordatum

Cuttings of Syzigium cordatum were mainly collected from two to three year old nursery grown trees which were vigorous in growth. These cuttings were handled rapidly to prevent deterioration and were forced under mist spray in a heated bed (21-23°C) (Hartmann et al., 1990). Coarse river sand (2-10 mm in diameter) was considered a suitable medium because of its water holding capacity and suitable drainage. Tables 1.12 and 1.13 depict propagation methods performed on Syzigium cordatum.

Table 1.12 River sand (2 mm in diameter) and bottom heat were used for Syzigium cordatum in a controlled greenhouse at 24-28°C and 10 sec./18 min. misting irrigation to compare type and length of cuttings, age of wood, and hormone treatments. (n = 40).

Type of cutting	Age of wood	Length of cutting (mm)	Hormone treatment
terminal	softwood	50-100	No.1 IBA powder
heel	softwood	100	6000 ppm IBA
straight stem	semi-hardwood	100	none
heel	softwood	100-150	No.2 IBA powder
stem	hardwood	100-150	No.3 IBA powder

A randomised block design was used to study the influence of the type, length and diameter of cuttings in a controlled greenhouse at 24-28°C and 10 sec./18 min. misting irrigation on the rooting success of Syzigium cordatum. Cuttings were all treated with No. 2 IBA powder and planted in coarse river sand (2-10 mm in diameter) with bottom heat (21-23°C).

See Table 1.13.

Table 1.13 Randomised block design to compare type, length and diameter of cuttings of Syzigium cordatum in a controlled greenhouse at 24-28°C and 10 sec./18 min. misting irrigation. (n = 90).

Type of cutting	Length of cutting (mm)	Diameter of cutting (mm)
terminal with heel	50-100	6-8
stem with heel	50-100	6-8
straight stem	50-100	6-8
terminal with heel	100-150	8-10
stem with heel	100-150	8-10
straight stem	100-150	8-10

CHAPTER 2

RESULTS

<u>Acacia</u> <u>mearnsii</u> and <u>A</u>. <u>melanoxylon</u>

Results for <u>Acacia</u> <u>mearnsii</u> and <u>A</u>. <u>melanoxylon</u> were combined for this study, as they showed similarities in growth and rooting. See Tables 2.1 and 2.2. Selecting cutting material for Australian <u>Acacia</u> species was difficult because the genotypic constitution of parent plants showed variation in growth rate and sometimes growth form. Invasive species used as cutting material are naturally propagated from seed with offspring of genetic variation. It was observed that the genetic variation affected rooting ability of cuttings selected from these species. See Tables 2.1 and 2.2.

Parent plants which were cut back on a regular basis tend to retain much of their juvenility and continued to force long, young shoots which were required for vegetative propagation. Cuttings taken from water shoots of parent plants survived for a longer period during the rooting process while improved results were obtained from thicker wood. See Tables 2.1 and 2.2.

Cuttings of partially matured wood appeared to be most successful. Semi-ripe stem cuttings maintained a 10% survival rate up to seven weeks after planting. See Tables 2.1 and 2.2. Root cuttings collected from young stock plants did not show any significant results in callusing either. See Table 2.2. Indications that thicker stems could possibly give improved results also did not live up to expectations. See Table 2.1.

Cuttings taken in summer and during the beginning of autumn were the most successful (10-20%). Cuttings taken during winter were not successful and rotted within four to eight weeks. All the leaves of these cuttings turned yellow and dropped during the eight week period. All soft tip and stem cuttings rotted within four weeks while thicker wood survived up to eight weeks with no further signs of improvement. See Tables 2.1 and 2.2.

Juvenile softwood cuttings of Acacia spp. subjected to a relative humidity of 70% and a temperature of 26°C survived longer than the hardwood cuttings kept under the same growth conditions. See Table 2.2. Australian Acacia species have fibrous stems which deteriorate fast in wet conditions. Irrigation was monitored to prevent excessive wet conditions. Cuttings survived thus better in a growth medium of coarse river sand which permitted maximum drainage. Cuttings that received too much moisture turned black and started to rot within two weeks. Leaves that were retained on cuttings dropped off one to two weeks after the cuttings were inserted.

Bottom heat used for rooting purposes resulted in no improvement in rooting. Internodal cuttings planted in the cold frame showed improved results over bottom heat of the same cuttings. A difference of 10% survival rate was measured over unheated cuttings.
See Table 2.2.

Girdling of cambium layers was induced to cause stress in parent plants. This procedure prevented downward transport of nutrients and hormones and increased nutrient supply to active growing points of the plants. Cuttings collected from these plants survived longer than those of plants which were not placed under stress. See Table 2.1. Cuttings collected from parent plants which were etiolated showed minimal changes from those collected from non-etiolated plants, however, these cuttings stayed alive in the propagation bed for a longer period. Cuttings with basal stems sealed in boiling water gave a 10% increased survival over those which received no treatment. See Table 2.2. By soaking cuttings in diluted kelp for five minutes the survival rate improved by 20%. See Table 2.2.

It was observed that water used as a rooting medium for Acacia melanoxylon caused a lack of aeration and was thus considered a great disadvantage for root initiation. Coarse river sand required more frequent watering to prevent desiccation of the roots which was detrimental to the survival rate of the cuttings.

For this study all attempts to initiate rooting were terminated after a twelve week period.

Table 2.1 Rooting success in Acacia mearnsii using different propagation methods, hormone treatments and rooting media. (n=45).

Type of cutting	Age of cutting	Length of cutting (mm)	Bottom heat	Hormone treatment	Rooting medium	Survival success (%) after 7 weeks	Callusing success (%) after 10 weeks
stem	semi-hardwood	250	no	No.2 IBA powder	1:1:1 bark sand polystyrene	10	0
terminal	softwood	150	no	No.1 IBA powder	1:1:1 bark sand polystyrene	0	0
stem	semi-hardwood	250	no	No.2 IBA powder	1:1 bark sand	10	0
terminal	softwood	150	no	No.1 IBA powder	1:1 bark sand	0	0
stem	semi-hardwood	250	no	No.2 IBA powder	sand	10	0
terminal	softwood	150	no	No.1 IBA powder	sand	0	0
stem	semi-hardwood	250	no	No.2 IBA powder	1:1 peat polystyrene	10	0
terminal	softwood	150	no	No.1 IBA powder	1:1 peat polystyrene	0	0
stem	semi-hardwood	250	no	No.2 IBA powder	bark	10	0
terminal	softwood	150	no	No.1 IBA powder	bark	0	0
terminal	softwood	150	no	refrigerated (10°C) callusing	sand	0	0
stem	hardwood	250-300	no	refrigerated (10°C) callusing	sand	0	0
stem	hardwood	250-300	no	excessive wounding refrigerated (10°C) callusing	sand	0	0
terminal soft	taken from girdled tree	150	no	No.2 IBA powder	sand	10	0
stem	semi-hard tip removed	150	no	No.2 IBA powder excessive wounding	sand	0	0
stem	semi-hardwood	100-200	yes	No.2 IBA powder	sand	10	0
terminal	softwood	100-200	yes	No.2 IBA powder	sand	0	0
stem (mallet)	softwood	150	yes	No.2 IBA powder	sand	0	0
terminal	softwood	100	yes	No.1 IBA powder	sand	0	0
stem (½ mallet)	softwood	100-150	yes	No.1 IBA powder	sand	0	0

Table 2.2 Rooting success in Acacia melanoxylon using different propagation methods, hormone treatments and rooting media. (n=45).

Type of cutting	Age of wood	Length of cutting (mm)	Bottom heat	Hormone treatment	Rooting medium	Survival success (%) after 7 weeks	Callusing success (%) after 10 weeks
stem	semi-hardwood	250-300	no	IBA 8000 ppm	sand	8	0
stem	semi-hardwood	250-300	no	refrigerated O°C/24 hrs. IBA 8000 ppm 5 sec.	sand	7	0
stem	semi-hardwood	250-300	no	10°C/24 hrs.IBA 8000 ppm 5 sec.	sand	7	0
stem	semi-hardwood	250-300	no	basal cut soaked in saltwater 5 g/l for 24 hrs.IBA 8000 ppm	sand	7	0
stem	semi-hardwood	250-300	no	dipped in boiling water for 60 sec.IBA 8000 ppm	sand	20	0
stem diameter 15 mm	semi-hardwood	300-400	no	IBA 4000 ppm	sand	10	0
stem diameter 15 mm	semi-hardwood	300-400	no	diluted Kelp/5 min.	sand	20	0
stem diameter 15 mm	semi-hardwood	300-400	no	No. 2 IBA powder	sand	10	0
stem diameter 15 mm	semi-hardwood	300-400	no	No. 3 IBA powder	sand	8	0
terminal	softwood	100-150	yes	No. 1 IBA powder	sand	0	0
terminal	softwood	100-150	no	No. 1 IBA powder	bark	7	0
terminal	softwood	100-150	no	No. 1 IBA powder	1:1:1 sand bark polystyrene	7	0
root	softwood	100-200	no	none	sand	10	0

Eucalyptus grandis

Juvenile growth taken from young trees which were cut back and allowed to re-shoot was found suitable for vegetative propagation of Eucalyptus grandis. Stems which were allowed to grow for three months on parent plants before cutting, proved to be successful for cutting material.

Soaking the cutting material longer than two days in water increased the deterioration of cutting material.

The season during which the plant material was collected has an effect on the response of cuttings. Stem cuttings showed improved results during the hotter months of the year with best results obtained from spring to summer. See Table 2.3. Young growth from Eucalyptus grandis showed positive signs of callusing from mature plants in early summer, however, cuttings could only be taken after four months when growth was mature enough to guarantee a positive response. Cuttings were ready to be harvested in mid-summer, i.e. during December.

Although Eucalyptus grandis cuttings showed positive results for survival at higher temperatures in a greenhouse under mist irrigation, unheated cuttings proved to be more successful than heated cuttings. See Table 2.3.

Callus formation of Eucalyptus grandis cuttings appeared after six weeks. See Table 2.3. After five weeks in the propagation bed, callusing of cuttings treated with 4000 ppm IBA increased by 20% over those which received a 8000 ppm IBA treatment. See Table 2.3. Thus cuttings treated with 4000 ppm IBA gave improved results of callus formation over 8000 ppm. IBA solution. See Table 2.3.

Coarse washed river sand was found to allow sufficient drainage, however, cuttings had to be sprayed weekly with a fungicide (6 g Benlate to 10 litres water) to prevent possible disease infection.

Excessive high ambient temperatures (above 28°C) had a negative effect on Eucalyptus grandis cuttings as callus formation was retarded. Temperatures above 30°C contributed to rotting of cuttings and other disease problems.

Table 2.3 Rooting success in Eucalyptus grandis using different propagation methods, hormone treatments and rooting media. Cuttings were taken during spring and early summer. (n=50).

Type of cutting	Age of wood (years)	Length of cutting (mm)	Bottom heat	Hormone treatment	Rooting medium	Callusing success (%) after 4 weeks	Callusing success (%) after 6 weeks
stem	2-3	250-300	no	8000 ppm IBA	river sand	0	40
stem	2-3	250-300	no	4000 ppm IBA	river sand	0	61
stem	2-3	250-300	no	8000 ppm IBA	1 bark: 1 river sand	0	35
stem	2-3	250-300	no	4000 ppm IBA	1 bark: 1 river sand	0	42

Ficus sur

Soft- to semi-hardwood cuttings of Ficus sur showed improved results over hardwood cuttings. See Table 2.4.

Cuttings measuring 60-120 mm and 120-180 mm resulted in 85% and 90% rooting success respectively after six weeks. Half mallet cuttings measuring 60 mm with two leaves resulted in 100% success in rooting. See Table 2.5. Half mallet cuttings with no leaves and stem lengths from 60-180 mm showed no rooting after six weeks. Half mallet cuttings with two to four leaves developed large root masses while signs of fresh growth from the growth tips developed four weeks after planting. See Table 2.5.

Cuttings taken during autumn and winter were slow and resulted in 40% rooting, whereas cuttings taken in early spring resulted in 80-100% success in rooting. See Tables 2.4 and 2.5. Cuttings were conducive to high humidity and high temperature levels and thus responded well to 60-70% relative humidity in the greenhouse. Moisture levels were kept high to prevent cuttings from drying out.

Bottom heat resulted in 80-100% success in rooting, whereas, cold frame conditions under mist irrigation resulted in 35% success. See Tables 2.4 and 2.5. Cuttings subjected to bottom heat initiated roots within two weeks, whereas unheated cuttings initiated roots within four weeks. Thus, bottom heat reduced the time required for root initiation by 50%. Significant differences between bottom heat and no heat on the dry mass of roots per cuttings were observed. Bottom heat enhanced root biomass by 2.5 fold over the no-heat treatment. See Tables 2.5 and 2.6.

Heel and half mallet cuttings treated with No. 2 IBA powder and planted in a rooting medium of 1 part sand, 1 part peat moss and 1 part polystyrene resulted in 10-20% rooting success after six weeks. Only 5% of mallet cuttings treated with No. 1 IBA powder rooted after six weeks while no rooting took place in stem cuttings after six weeks. Cuttings treated with No.3 IBA powder resulted in 100% rooting success whereas 50% rooted after six weeks with No. 2 IBA powder. See Table 2.6.

Visual observations showed that wounding gave improved results over cuttings which were not wounded. Wounding basal stem treatment resulted in 80-100% rooting success of Ficus sur cuttings. See Table 2.5.

Ficus sur cuttings in a mixture of 1:1 peat/polystyrene resulted in 80-100% rooting success. A sand rooting medium gave 15% success in rooting whereas a mixture of 1:1:1 peat, sand and vermiculite resulted in 20% rooting success after six weeks.

Table 2.4 Rooting success in Ficus sur semi-hardwood cuttings using different propagation methods, hormone treatments and rooting media. (n=45).

Type of cutting	Length of cutting (mm)	Bottom heat	Hormone treatment	Rooting medium	Callusing success (%) after 4 weeks	Rooting success (%) after 6 weeks
stem/nodal	60-120	yes	No.2 IBA powder	1:1 peat polystyrene	0	0
stem/internodal	60-120	yes	No.1 IBA powder	1:1 peat polystyrene	3	2
stem/heel	60-120	yes	No.3 IBA powder	1:1 peat polystyrene	15	20
stem/nodal	120-180	yes	No.2 IBA powder	river sand	5	2
stem/internodal	120-180	yes	No.1 IBA powder	river sand	0	0
stem/mallet	120-180	yes	No.3 IBA powder	river sand	12	10
stem/nodal	60	yes	No.2 IBA powder	river sand	0	0
stem/internodal	60	yes	No.1 IBA powder	river sand	0	0
stem/heel	60	yes	No.3 IBA powder	river sand	17	15
½ mallet/ shoot tip removed	60-120	no	No.2 IBA powder	1:1:1 peat sand vermiculite	8	10
½ mallet/ shoot tip removed	60-120	no	No.3 IBA powder	1:1:1 peat sand vermiculite	25	20
½ mallet/ shoot tip removed	60-120	no	No.1 IBA powder	1:1:1 peat sand vermiculite	11	5

Table 2.5 Rooting success in Ficus sur using different lengths of cuttings, number of leaves and bottom heat/no heat treatments. Half mallet cuttings were taken in spring, treated with No. 3 IBA powder and grown in 1 peatmoss : 1 polystyrene rooting mixture. (n=90).

Length of cutting (mm)	**Number of leaves**	**Bottom heat**	**Callusing success (%) after 4 weeks**	**Rooting success (%) after 6 weeks**
120-180	0	yes	45	40
60-120	0	yes	60	61
60	0	yes	60	54
120-180	2	yes	55	60
60-120	2	yes	91	80
60	2	yes	97	100
120-180	0	no	15	10
60-120	0	no	21	15
60	0	no	17	15
120-180	2	no	72	67
60-120	2	no	75	70
60	2	no	75	75
120-180	2-4	yes	83	80
60-120	2-4	yes	80	85
60	2-4	yes	85	80
120-180	2-4	no	17	15
60-120	2-4	no	16	10
60	2-4	no	22	18

Table 2.6 Rooting success in Ficus sur using different types of cuttings, bottom heat/no heat and hormone treatments.

Auxin treatment	**½ Mallet no leaves**		**½ Mallet 2 – 4 leaves**		**Heel**	
	Rooting success (%)		**Rooting success (%)**		**Rooting success (%)**	
	Bottom heat	**No heat**	**Bottom heat**	**No heat**	**Bottom heat**	**No heat**
No. 1 IBA	0	5	0	0	0	0
No. 2 IBA	0	10	0	0	0	0
No. 3 IBA	0	15	80-100	18	15	20

Melia azedarach

Thicker and woodier cuttings gave improved results over thinner, semi-hardwood cuttings. Hardwood cuttings did not perish easily and required no special equipment during rooting.

Harder wood cuttings taken during early spring resulted in 50% callusing, however, no rooting was found. Deciduous tip cuttings taken in winter developed new leaves within three weeks, but did not develop any further. A total of 90% of these cuttings dropped their leaves after six weeks and showed no signs of rooting. Hardwood stem cuttings with the terminal shoots remaining showed a 30% improvement over those stem cuttings wounded on both ends. See Table 2.7. After six weeks, hardwood truncheon cuttings measuring 200-300 mm callused whereas softer stem cuttings did not develop any signs of rooting. See Table 2.7.

All cuttings were kept in a greenhouse with a 70-80% humidity. No significant difference in results were observed, however, buds of tip cuttings started to enlarge after two weeks whereas buds of all stem cuttings started to develop after three weeks in the greenhouse. All buds continued to develop, but 50% turned brown after the third week. All cuttings dropped their leaves after four weeks in the greenhouse and no rooting could be measured at this stage.

Cuttings subjected to bottom heat showed 20% success in callusing, however, 30% callusing success was achieved with thicker wood internodal cuttings. These cuttings started to shoot new leaves after six weeks, but did not develop any further. Cuttings subjected to cold frame conditions indicated 20% improved results over those which received bottom heat. Various basal stem treatments were used to enhance rooting. Both treatments where cuttings were dipped in boiling water for five seconds or sealed with paper glue resulted in 50% callusing success after six weeks. Hormone treatments of various concentrations e.g. No.3 IBA powder, 4000 ppm IBA solution, and No.1 IBA powder did not show any improvement or variation in results. Tip and stem cuttings which were treated with 8000 ppm IBA, developed new leaves within three to four weeks, but all leaves dropped after six weeks. See Table 2.8.

River sand, which was a more obvious choice for thicker stem cuttings improved the survival success compared to mixtures of 1:1 river sand and peat moss and 1:1:1 river sand, bark and polystyrene. See Table 2.7. A rooting medium consisting of 1:1 peat and polystyrene resulted in 20% callusing success of cuttings taken in late winter whereas cuttings planted in sterile, washed river sand resulted in 25% callusing success. Cuttings showed improved results with drainage of excess water. After eight weeks only the cuttings which were planted in river sand retained their leaves. All other cuttings either did not show any signs of renewed growth or were dead in the propagation medium by this time.

Table 2.7 Rooting success in Melia azedarach using different propagation methods, hormone treatments and rooting media. (n=45).

Type of cutting	Age of wood	Length of cutting (mm)	Bottom heat	Hormone treatment	Rooting medium	Callusing success (%) after 6 weeks	Rooting success (%) after 10 weeks
stem with tip	hardwood	200-250	no	No.3 IBA powder (glue)	river sand	50	0
stem with tip	hardwood	200-250	no	8000 ppm IBA	river sand	8	0
stem with tip	hardwood	200-250	no	4000 ppm IBA (hot water)	river sand	50	0
stem	hardwood	200-300	no	No.3 IBA powder	river sand	25	0
stem	hardwood	200-300	no	8000 ppm IBA	river sand	7	0
stem	hardwood	200-300	no	4000 ppm IBA	river sand	9	0
stem with tip	hardwood	200-250	no	No.3 IBA powder	1:1 peat sand	11	0
stem with tip	hardwood	200-250	no	8000 ppm IBA	1:1 peat sand	1	0
stem with tip	hardwood	200-250	no	4000 ppm IBA	1:1 peat sand	1	0
stem	hardwood	200-300	no	No.3 IBA powder	1:1 peat sand	2	0
stem	hardwood	200-300	no	8000 ppm IBA	1:1 peat sand	0	0
stem	hardwood	200-300	no	4000 ppm IBA	1:1 peat sand	1	0
stem with tip	hardwood	200-250	no	No.3 IBA powder	1:1:1 sand bark polystyrene	3	0
stem with tip	hardwood	200-250	no	8000 ppm IBA	1:1:1 sand bark polystyrene	0	0
stem with tip	hardwood	200-250	no	4000 ppm IBA	1:1:1 sand bark polystyrene	0	0
stem	hardwood	200-300	no	No.3 IBA powder	1:1:1 sand bark polystyrene	2	0
stem	hardwood	200-300	no	8000 ppm IBA	1:1:1 sand bark polystyrene	1	0

Tabel 2.7 continues

Type of cutting	**Age of wood**	**Length of cutting (mm)**	**Bottom heat**	**Hormone treatment**	**Rooting medium**	**Callusing success (%) after 6 weeks**	**Rooting success (%) after 10 weeks**
stem	hardwood	200-300	no	4000 ppm IBA	1:1:1 sand bark polystyrene	0	0
stem with tip	hardwood	200-250	no	No.3 IBA powder	1:1 peat polystyrene	2	0
stem with tip	hardwood	200-250	no	8000 ppm IBA	1:1 peat polystyrene	0	0
stem with tip	hardwood	200-250	no	4000 ppm IBA	1:1 peat polystyrene	1	0
stem	hardwood	200-300	no	No.3 IBA powder	1:1 peat polystyrene	0	0
stem	hardwood	200-300	no	8000 ppm IBA	1:1 peat polystyrene	0	0
stem	hardwood	200-300	no	4000 ppm IBA	1:1 peat polystyrene	0	0
stem with tip	hardwood	200-250	yes	No.3 IBA powder	river sand	30	0
stem with tip	hardwood	200-250	yes	8000 ppm IBA	river sand	28	0
stem with tip	hardwood	200-250	yes	4000 ppm IBA	river sand	31	0
terminal	softwood	50-100	yes	No.1 IBA powder	river sand	1	0
terminal	softwood	50-100	yes	No.1 IBA powder	river sand	0	0
terminal	softwood	50-100	yes	No.1 IBA powder	river sand	0	0

Table 2.8. Results of plant responses in Melia azedarach on cutting treatments, condition of plant, age of wood and type of cutting.

				Survival rate of cuttings (weeks after planting)		
Treatment	**Plant response**	**Age of wood**	**Type of cutting**	**6**	**8**	**10**
taken in winter	leaf drop	juvenile	tip		90 %	
river sand	callusing	hardwood	stem	25 %		
8000 ppm IBA	new leaves	hardwood	stem	50 %		
sealed paper glue	callusing	hardwood	stem	50 %		
taken in spring	callusing	hardwood	stem			50 %
bottom heat	callusing	thicker wood	stem	30 %		
wounding ends	callusing	hardwood	truncheon		50 %	

Olea europaea subsp. africana

Rooting studies for the first year of this study resulted in low rooting success amongst the few selections that rooted. Olea europaea subsp. africana rooted relatively slowly, but rooting was more successful in parent plants which showed genetic variations in growth, i.e. leaf size, vigour and leaf colour. The most promising results were obtained with selections of plants with smaller leaves. See Tables 2.10 and 2.11.

Both harder wood and semi-ripe wood was tested. Small cuttings selected from young vigorous growth tips which have matured gave improved results over harder wood cuttings. See Table 2-9. Apart from achieving success in rooting, parent plants were cut back to keep them in a strong, vegetative condition. Plants which were cut back on a regular basis tend to retain much of their juvenility and continued to re-shoot with long vegetative shoots. These young shoots were also used for stem cuttings. Short heel cuttings (70-120 mm long) resulted in 10% rooting success in autumn within six weeks from striking while longer mallet cuttings resulted in 5% rooting. Thus the smaller the cuttings, the better the rooting results. See Table 2.9.

Tip cuttings with two leaves taken during spring showed no rooting success, however, tip cuttings (50 mm long) with two to four leaves treated with no.2 IBA powder resulted in 75% callusing success and rooted within four to six weeks. See Table 2.9. Roots up to 100 mm long were measured in the latter treatment.

Mallet cuttings kept under mist resulted in 75% rooting success when treated with IBA at 4000 ppm. See Table 2.10. Twenty-five percent of mallet cuttings showed signs of callusing within four weeks. See Table 2.9.

Another determining factor was the season during which the cuttings were collected. See Fig. 2.1. The rooting success decreased rapidly from mid-summer throughout early winter. Cuttings taken during late summer and autumn were kept for up to 14 weeks in the beds before discarded. Of these cuttings 20-50% died in summer and autumn. Cuttings taken during July, however, were the most successful and resulted in 80% rooting success. See Table 2.11. The rooting period during this time was reduced to four weeks. Cuttings taken in early to mid-summer under 80% humidity resulted in 60% rooting success.

At least a 70% humidity level was required to induce root formation. This was maintained in the greenhouse with intermitting irrigation. However, higher humidity levels retarded root formation.

Coarse river sand proofed to be a successful rooting medium, but required more frequent watering to prevent desiccation which was detrimental during rooting. See Table 2.11. One difficulty that affected results was the river sand which dried out on top of the propagation bed in mid-summer and it is assumed that rooting was decreased as a result. River sand could only be used once unless it was re-sterilized. Combinations of other media were more successful in rooting, e.g. up to 80%. See Table 2.11.

Table 2.9 Rooting success in Olea europaea subsp. africana using different propagation methods, age of wood, lengths of cuttings and hormone treatments. (n=45).

Type of cutting	Age of wood (years)	Length of cutting (mm)	Hormone treatment	Callusing success (%) after 4 weeks	Rooting success (%) after 6 weeks
straight stem	1-2	100-300	No.2 IBA powder	29	27
heel	1-2	100-200	No.2 IBA powder	31	33
½ mallet	1-2	100-300	No.2 IBA powder	35	5
heel tip	2	70-120	No.2 IBA powder	31	10
½ mallet	2	100-300	No.2 IBA powder 1-2 hrs. soaking	65	69
terminal	1-2	50	No.2 IBA powder/ 1000 ml H_2O. 2 hrs. soaking	80	75
terminal	1-2	100-150	store at 10°C for 60 days	25	10
terminal	1-2	100-200	4000 ppm IBA	60	55
terminal	1-2	50-100	2000 ppm IBA	46	40
terminal	2	200-250	8000 ppm IBA	13	10

Table 2.10 Rooting success in Olea europaea subsp. africana using different type and diameter of cuttings, number of leaves and distance from apex of cuttings. Cuttings were taken during late winter and spring, treated with 4000 ppm IBA and grown in coarse river sand with bottom heat. (n=90).

Type of cutting	No. of leaves	Distance from apex (mm)	Diameter of cutting (mm)	Callusing success (%) after 4 weeks	Rooting success (%) after 6 weeks
terminal	0	0-50	5	77	66
terminal	2	0-50	5	79	75
terminal	4	0-50	5	81	71
terminal	0	50-100	8	66	69
terminal	2	50-100	8	80	77
terminal	4	50-100	8	75	71
terminal	0	100-150	10	71	66
terminal	2	100-150	10	78	71
terminal	4	100-150	10	73	70
stem	0	50-100	5	35	40
stem	2	50-100	5	40	41
stem	4	50-100	5	39	35
stem	0	100-150	8	34	36
stem	2	100-150	8	39	42
stem	4	100-150	8	35	39
stem	0	150-200	10	29	34
stem	2	150-200	10	41	37
stem	4	150-200	10	50	39
mallet	0	50-100	5	61	67
mallet	2	50-100	5	66	71
mallet	4	50-100	5	61	65
mallet	0	100-150	8	72	67
mallet	2	100-150	8	80	75
mallet	4	100-150	8	80	71
mallet	0	150-200	10	60	64
mallet	2	150-200	10	68	66
mallet	4	150-200	10	59	61

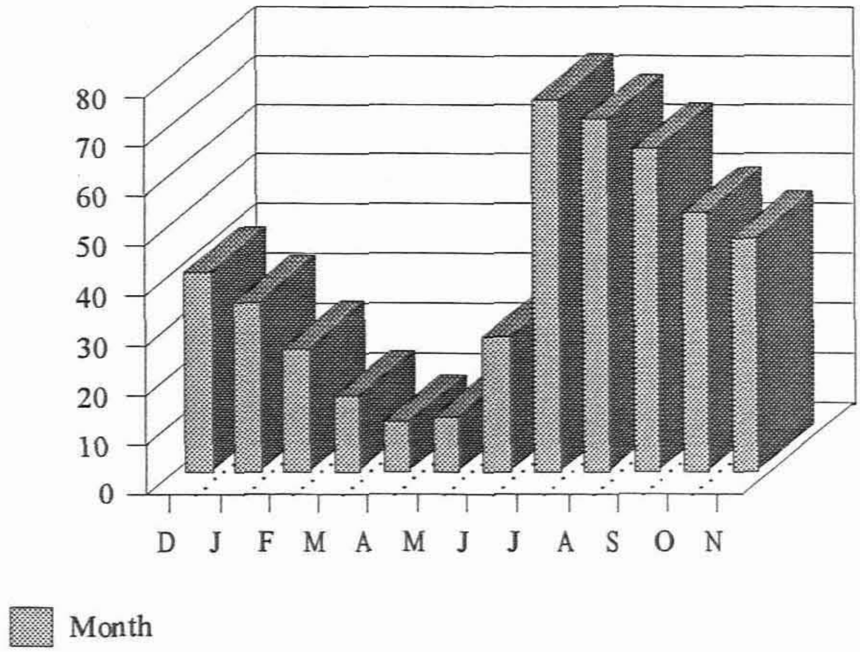

Fig. 2.1 Rooting success in Olea europaea subsp. africana during different seasons.

Table 2.11 Rooting success in Olea europaea subsp. africana using different types of rooting media during late winter and spring. (n=90).

Type of cutting	No. of leaves	Distance from apex (mm)	Diameter of cutting (mm)	Rooting medium	Callusing success (%) after 4 weeks	Rooting success (%) after 6 weeks
tip with mallet	2	100-150	8	1:1:1 peat sand polystyrene	72	75
tip with mallet	2	100-150	8	1:1:1 peat vermiculite polystyrene	81	80
tip with mallet	2	100-150	8	1:1 peat polystyrene	70	66
tip with mallet	2	100-150	8	river sand	75	71

Podocarpus falcatus

Softer wood cuttings were more successful (60%) over semi-hardwood (40%). Hardwood cuttings were 60% slower in showing signs of new growth and root formation. See Tables 2.12 and 2.13. Young shoots after a flush of new growth were found too soft for propagation purposes. Terminal cuttings were 30% more successful over stem cuttings of semi-matured wood while mallet and half mallet cuttings were not as successful (25%) as anticipated. See Table 2.12. The length of cuttings did not affect the rooting period, however, cutting length of 100-200 mm was preferred for this study. See Table 2.13.

The highest rooting success (60%) was obtained in cuttings collected during February and March and the lowest success rate (20%) was obtained in cuttings collected during May and June. Thus cuttings taken during spring and early summer rooted noticeably slower than cuttings taken in late summer. Cuttings taken in late winter were less successful (30%) in rooting than those which were taken in early winter (40%). These cuttings took six weeks before any root initiation could be observed, and should not be disturbed before this time.

Podocarpus falcatus cuttings required a 70% humidity regime, however, too wet conditions were not conducive to promoting rooting. Watering had to be controlled by overhead misting and using a well drained growth medium. Cuttings resulted in 40% rooting success in coarse river sand with bottom heat at 21°C in the greenhouse. See Table 2.12.

Initial signs (after four to six weeks) of rooting appeared to be slow, however, rooting success increased after eight weeks.

Cuttings were faster to root with bottom heat than those planted in cold frames. See Table 2.13. Heated cuttings showed signs of rooting within eight weeks after striking. However, those without heat only started root initiation after 16 weeks, thus cuttings were slower to root in cold frames. Bottom heat reduced the period required for root initiation but, also showed improved results of root biomass over the cuttings grown in unheated beds.

In this study, wounding alone appears to have a small effect on the dry mass of roots per cutting or the percentage of rooting (30%). However, wounding interacted with bottom heat which gave improved results. See Table 2.13. Visual observation showed that cuttings with bottom heat treatment and by splitting the base produced 60% more root biomass than those in cold frames. Under non-heated conditions, root biomass was similar between wounded and non-wounded cuttings. See Table 2.12.

Various concentrations of hormone treatment, ranging from 1-8%, were applied to cuttings. A two percent concentration gave the highest (60%) rooting success. Cuttings responded better to an IBA powder (60%) than to a liquid treatment (40%). See Tables 2.12 and 2.13.

The various growth media used for this study did not show any significant variation in results. However, coarse (1-10 mm diameter) washed river sand was preferred over bark, polystyrene and peat moss. River sand improved drainage and was easier to use with bottom heat, when cuttings were planted directly into the bed.

Table 2.12 Rooting success in Podocarpus falcatus using different types and lengths of cuttings, age of wood, bottom heat, hormone treatments and rooting media. (n=45).

Type of cutting	Age of wood	Length of cutting (mm)	Bottom heat	Hormone treatment	Rooting medium	Callusing success (%) after 6 weeks	Rooting success (%) after 8 weeks
½ mallet with tip	semi-hardwood	150	no	No.2 IBA powder	bark	32	23
terminal	softwood	100	no	No.1 IBA powder	bark	1	38
½ mallet with tip	semi-hardwood	150	no	No.2 IBA powder	1:1 sand bark	34	25
½ mallet with tip	semi-hardwood	150	no	No.2 IBA powder	1:1:1 sand bark polystyrene	29	23
terminal	softwood	100	no	No.1 IBA powder	1:1:1 sand bark polystyrene	39	35
terminal	softwood	100	no	No.1 IBA powder	sand	48	40
½ mallet with tip	semi-hardwood	150	no	No.2 IBA powder	sand	33	25
terminal	softwood	100	no	No.1 IBA powder	sand	42	38
terminal	softwood	150	no	No.1 IBA powder	sand	40	42
terminal with mallet	semi-hardwood	150	no	No.1 IBA powder	sand	17	21
stem	semi-hardwood	150	no	No.2 IBA powder	sand	40	42
tip/stem	semi-hardwood	100-150	yes	8000 ppm IBA	sand	31	20
tip/stem	semi-hardwood	100-150	yes	4000 ppm IBA	sand	34	25
tip/stem	semi-hardwood	100-150	yes	2000 ppm IBA	sand	37	40
tip/stem	semi-hardwood	100-150	yes	1000 ppm IBA	sand	33	21
stem tip ½ mallet	softwood	100-150	no	No.1 IBA powder	1:1 peat polystyrene	40	35
terminal	softwood	100-150	no	No.1 IBA powder	1:1 peat polystyrene	31	39
stem tip ½ mallet	softwood	100-150	no	no.2 IBA powder	sand	41	55

Table 2.13 Rooting success in Podocarpus falcatus using different types and lengths of cuttings, and number of leaves. Cuttings were all treated with No. 2 IBA powder and planted in coarse river sand with bottom heat. (n=90).

Type of cutting	Length of cutting (mm)	Number of leaves	Callusing success (%) after 6 weeks	Rooting success (%) after 8 weeks
terminal	100-150	2-6	60	60
stem	100-150	2-6	55	60
terminal	150-200	2-6	65	60
stem	150-200	2-6	51	58
terminal	100-150	none	41	37
stem	100-150	none	50	51
terminal	150-200	none	35	38
stem	150-200	none	44	48

Syzigium cordatum

Cuttings selected from young nursery seedlings from the current year's growth resulted in 90% rooting. See Table 2.15. Juvenility enhanced the rooting of Syzigium cordatum. A 60-90% rooting success was obtained using juvenile cutting material collected from container grown specimens. Results proved that 80% of juvenile cuttings taken from two months old growth rooted at 26°C. Older and thicker wood cuttings were slower to root (7-8 weeks), however, cuttings taken with a heel resulted in 80-90% success, whereas straight stem cuttings resulted in 60-70% success. See Tables 2.14 and 2.15.

A total of 85% of the small tip cuttings callused within four weeks after insertion and rooted within six weeks. See Table 2.14. No.1 IBA powder was used for these cuttings. Heel cuttings started callusing six weeks after cutting and rooting took place eight weeks after the cuttings were made. A 80-90% success rate was obtained from heel cuttings. See Table 2.15. Stem cuttings took up to eight weeks to callus and were thus slower to root than heel cuttings.

See Table 2.14. Tip cuttings rooted faster (6 weeks) than stem cuttings (7-8 weeks), but the latter developed stronger roots and improved the quality of the plants. Shorter cuttings (50-100 mm) were more successful than longer ones (100-150 mm). See Table 2.15.

Rooting success of 85-90% were recorded at the end of winter and towards the beginning of spring in a medium of coarse river sand. Cuttings resulted in 15% rooting success during winter. See Fig. 2.2. High humidity and temperatures were of advantage to the rooting of cuttings, whereas lower temperatures under wetter conditions indicated slower results.

Bottom heat improved the rooting success of Syzigium cordatum cuttings. Maximum rooting success (90%) of Syzigium cordatum cuttings occurred after six weeks of bottom heat treatment, yet the magnitude of the rooting response decreased with increased exposure to lower temperatures in winter. In contrast, increased exposure of cuttings to bottom heat resulted in a progressive increase in rooting. Rooting success of cuttings planted in the cold frame were low (15%), whereas bottom heating maintained a warmer (21-23°C) environment in the root zone. Larger wounds enhanced the development of more callus growth which improved the root mass. Cuttings which were dipped in a solution of 6000 ppm IBA started callusing within six weeks and rooted within eight weeks See Table 2.14. Cuttings which were planted without any treatment were slow (7 weeks) to develop callus.

River sand (2-10 mm diameter) provided the cuttings with sufficient moisture and drainage and was found to be the most successful rooting medium compared to bark and peat moss based media which hold more water. See Table 2.15.

Table 2.14 Rooting success in Syzigium cordatum using different types and lengths of cuttings, age of wood, and hormone treatments. (n=40).

Type of cutting	Age of wood	Length of cutting (mm)	Hormone treatment	Callusing success		Rooting success	
				%	weeks	%	weeks
terminal	softwood	50-100	No.1 IBA powder	85	5	85	6
heel	softwood	100	6000 ppm IBA	70	5	75	8
straight stem	semi-hardwood	100	none	71	7	70	8
heel	softwood	100-150	No.2 IBA powder	90	5	86	6
stem	hardwood	100-150	No.3 IBA powder	60	7	64	8

Table 2.15 Rooting success in Syzigium cordatum using different types, lengths and diameter of cuttings. Cuttings were all treated with No. 2 IBA powder and planted in coarse river sand with bottom heat. (n=90).

Type of cutting	Length of cutting (mm)	Diameter of cutting (mm)	Callusing success		Rooting success	
			%	week	%	week
terminal with heel	50-100	6-8	81	5	80	6
stem with heel	50-100	6-8	90	5	90	6
straight stem	50-100	6-8	75	6	70	7
terminal with heel	100-150	8-10	80	6	80	7
stem with heel	100-150	8-10	86	5	80	6
straight stem	100-150	8-10	69	7	72	8

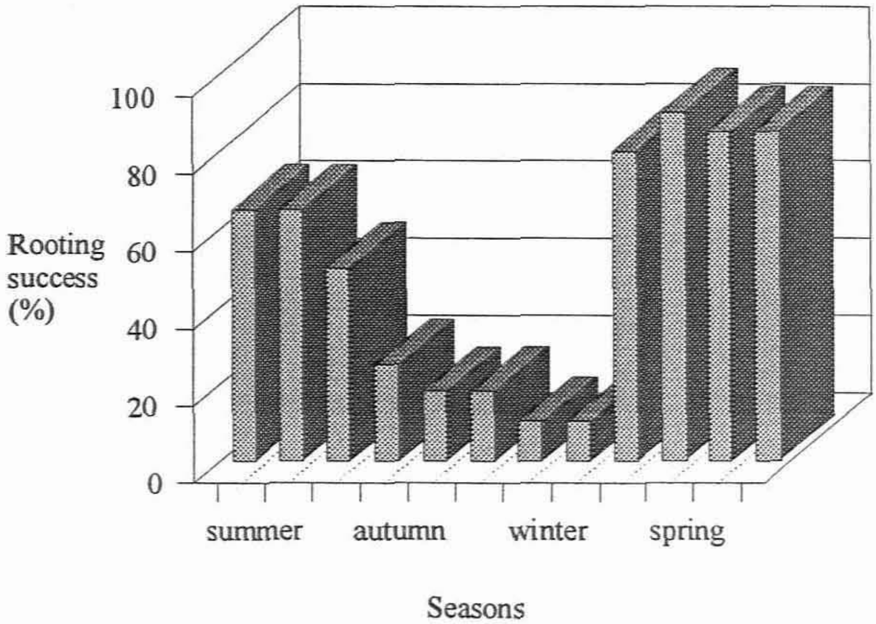

Fig. 2.2 Rooting success in Syzigium cordatum cuttings prepared from juvenile nursery stock collected during different seasons.

Table 2.16 Comparisons of callusing/rooting success using different rooting media for different plant species.

Species	Rooting Medium	Callusing/Rooting Success (%)
Acacia mearnsii *Acacia melanoxylon*	river sand	10
Eucalyptus grandis	river sand	61
Ficus sur	1:1 peat/polystyrene	100
Melia azedarach	river sand	50
Olea europaea subsp. *africana*	river sand	75
Podocarpus falcatus	river sand	65
Syzigium cordatum	river sand	90

Table 2.17 Rooting success (%) using different concentrations of rooting hormones on different plant species.

Rooting hormones	*Acacia mearnsii* *Acacia melanoxylon*	*Eucalyptus grandis*	*Ficus sur*	*Melia azedarach*	*Olea europaea* subsp. *africana*	*Podocarpus falcatus*	*Syzigium cordatum*
none	0	0	0	0	0	0	10
No.1 IBA powder	0	not used	10	0	not used	15	85-90
No.2 IBA powder	0	not used	20	not used	75%	65	68
No.3 IBA powder	0	not used	80-100	0	not used	not used	34
2000 ppm IBA	not used	not used	not used	not used	15%	10	75
4000 ppm IBA	0	0	not used	0	75%	not used	58
6000 ppm IBA	not used	not used	not used	not used	not used	not used	27
8000 ppm IBA	0	0	not used	0	2%	not used	15

CHAPTER 3

CONCLUSION AND RECOMMENDATIONS

Vegetative propagation of selected plant species for this study was not only limited to preparing cuttings and planting them in a rooting medium. Even though this may define the process, far more is involved (Hartmann et al., 1990). The possibility for cuttings to initiate roots, as opposed to rot, depends on a number of factors, e.g. the season during which the cutting is taken, the age, type and length of the cutting, environmental factors and the rooting media used.

Acacia mearnsii and A. melanoxylon

This study found that genetic variation in Australian Acacia species restricts the rooting process. A. melanoxylon is a self-pollinator and genetic variation of individuals occurs naturally through seed propagation (De Zwaan, 1982). Selecting cutting material for the present study of Acacia species was difficult, because the genotypic constitution of parent plants also varies as regards growth rate and shape of the crown and stem, as well as the quality of wood (De Zwaan, 1982). Characteristics which vary within the same species may thus influence the particular propagation technique. De Zwaan (1982) reported that trials with Australian, Tasmanian and South African material revealed significant differences among plants from various regions. A. melanoxylon specimens from the northern parts of South Africa differ from those which occur in the eastern and southern parts. The abovementioned factors must be considered when cutting material is selected as they may influence the ability and speed of rooting, and the quality of the roots.

The present study revealed that both Acacia mearnsii and A. melanoxylon have fibrous stems which deteriorate rapidly, either from desiccation or from rotting. Cutting material requires rapid handling during transportation and storage before the cuttings are made. Wet conditions and irrigation water in particular must be avoided or strictly monitored to prevent excessive flooding and deterioration of cuttings. Drainage during rooting must allow excess water to be removed from the growth medium. Cuttings turn black, leaves drop and stems rot in the presence of too much moisture.

Indications that relatively thick (5-10 mm) stems of Australian Acacia spp. would root did not live up to expectations. These results were based on an extended survival rate of cuttings from mature wood. See Tables 2.1 and 2.2. Results of mature tissue being more difficult to root are in agreement with Glocke & Sedgley (1995), who revealed that internal changes within mature tissue are relatively unknown. However, tissue at the base of mature plants remains juvenile, whereas terminal cuttings from older tissue have less rooting ability. Cuttings of partially matured or semi-ripe wood appeared to be more successful in the present study. Hartmann et al. (1990) explained that root growth in cuttings is dependent on available carbohydrates in plants. The juvenile period, however, can be affected by environmental conditions, genetic factors and diseases (Glocke & Sedgley, 1995). Cuttings taken from watersprouts of mother plants remained fresh for a longer period during the rooting process, while improved callusing was obtained from thicker wood. See Tables 2.1 and 2.2. Hackett (1985) suggested that basal shoots can be induced by severe pruning and consequently coppicing, or treatment with plant regulators to retard growth in order to extend the juvenile phase. It is therefore recommended that juvenile material obtained from mature plants be collected from the lower parts in the crown of parent plants, as suggested by Glocke & Sedgley (1995).

Root cuttings were unsuccessful despite the fact that A. melanoxylon spreads vegetatively by suckering from surface roots which can surround mature trees with thousands of root suckers (Macdonald et. al., 1986).

Late-winter to early-spring appears to be the most favourable season for rooting cuttings, however, further experimentation is required. Most Australian Acacia species flower from late-winter to spring (Coats Palgrave, 1983). The season to take cuttings is important, as most plants utilize carbohydrates and food reserves at a higher rate when not flowering or producing seed (Hartmann et al., 1990). For this reason cuttings taken during summer and autumn proved to be most successful. See Tables 2.1 and 2.2. This study revealed that despite the fact that winter is not a favourable season for striking cuttings, mature wood survives longer than juvenile wood during this period. See Tables 2.1 and 2.2.

Juvenile softwood prefers a higher, i.e. 70% relative humidity compared to mature wood, i.e. 50%. See Tables 2.1 and 2.2. Bottom heat affected the cuttings negatively, while cold frame conditions gave positive results. See Tables 2.1 and 2.2. Cuttings affected by bottom heat turned black after six weeks.

The fact that beneficial after-effects of girdling on parent plants on the growth increment of the cuttings were observed, further suggests that subsequent rooting and growth of the cuttings do improve by placing parent plants under stress. This confirms the theory of Hartmann et al. (1990) that girdling improves rooting success in cuttings. Girdling of plant stems prevents downward transport of nutrients and hormones and increases the nutrient supply to specific areas of the plant. Even cuttings collected from girdled parent plants survived up to seven weeks in the propagation bed. See Table 2.1. It is well documented (Hartmann et al., 1990) that etiolation can improve adventitious rooting. However, the response might differ among different species. For example, juvenility improved rooting in Acacia baileyana, while it did not improve rooting in A. imbricata, A. glaucoptera, A. podalyriifolia, A. polybotrya and A. vestita (Glocke & Sedgley, 1995).

Sealing basal stem cuttings to prevent water loss or potential leaching of chemical inhibitors and thus inhibit callus formation (Glocke & Sedgley, 1995) and possibly death of cuttings are factors which need further investigation. Basal ends sealed in boiling water during this study did, however, increase the rooting success over those that received no treatment.
See Table 2.2.

The selection and isolation of parent plants are necessary to establish a gene pool which can be maintained for future vegetative propagation of Acacia mearnsii and A. melanoxylon. The development of a viable economic method of vegetative propagation will not only replace existing fertile invasive vegetation with sterile plants but will continue to benefit industry, provide rural and urban communities with low-cost wood, and simultaneously be no threat to the natural vegetation of South Africa.

Thus far attempts to propagate Acacia mearnsii and A. melanoxylon vegetatively have not been successful. Despite the use of a variety of types of cuttings, from soft tip shoots to mature hardened growth, and the use of a number of different hormonal rooting compounds and growth media, cuttings remained difficult to root. The success rate proved to be no more than extending the survival rate of cuttings. More research in vegetative propagation as regards growth conditions, girdling and etiolation is required. A different approach to cultivation is obviously required. For this reason, layering and air-layering should be attempted on existing parent plants.

In conclusion, results from the present study suggest Acacia mearnsii and A. melanoxylon cuttings should be of the semi-hardwood heel or mallet type and 75-100 mm long. Cold frame conditions will improve both quality and growth of cuttings harvested from juvenile parent plants in early- to mid-summer.

Eucalyptus grandis

Trials to propagate Eucalyptus grandis vegetatively have been successful, however, only juvenile growth taken from young trees which were cut back, are apparently suitable for vegetative propagation. A similar response for Eucalyptus spp., reported by Eldridge et al. (1994), revealed that mature tissue is more difficult to root. In addition to increasing cutting yield, maintaining juvenile growth on parent plants with regular pruning, also improved selection of cutting material. This is a common response in parent plants subjected to severe coppicing of older stems and is in agreement with Eldridge et al. (1994) who reported that coppicing of older trees provide good juvenile cuttings for vegetative propagation. Growth, however, has to mature for at least three to four months before cuttings can be taken.

Cuttings collected in spring and early-summer, when callusing appears to be rapid, yielded the best results. See Table 2.3. This study verifies reports by Eldridge et al. (1994) that Eucalyptus cuttings root well when collected throughout summer. Cuttings prefer cold frame conditions over bottom heat. When using bottom heat, cambium layers turned brown to black before callusing took place. Temperatures ranging from 18-26°C in the greenhouse yielded good results, while higher temperatures had a negative influence. Rooting hormone treatments of 4000 ppm IBA and a cutting length of 250-300 mm gave best results in Eucalyptus grandis. See Table 2.3.

Soaking cuttings in a fungicide treatment of 6 g Benlate/Dithane to 10 litres water once a week proved essential as a preventative measure. This response is in agreement with the findings of Eldridge et al. (1994) who reported that fungicidal treatments must be strictly followed to ensure the survival of Eucalyptus grandis cuttings during the rooting process. Drainage was found essential during the rooting process in the present study, and was provided by coarse (2-10 mm diameter), washed and relatively sterile river sand.

Further suggestions to induce rooting in Eucalyptus grandis are to place parent plants under stress before cuttings are taken. Plants which grow with a restricted water supply usually produce firmer shoots and have a higher water-use efficiency (Hartmann et al., 1990). This could be turned to good effect if the water supply to the parent plants is reduced prior to cutting removal. Cuttings produced in this manner should thus have a lower tendency to develop moisture-stress in the propagation environment.

Plants can also be placed under stress by reducing nutrient applications (Janick, 1986). The availability of nutrients during the rooting process can influence root formation. He revealed that rooting can be delayed or prevented by a nutrient deficiency, however, cuttings from many species which are difficult to root do not respond to auxin application. This factor is further influenced by the change from juvenility to maturity. The forming of inhibitors block rooting during maturity in plants. Thus leaching plant material in water can promote rooting, however, too much soaking may lead to deterioration of cuttings. A similar response can be obtained by soaking cuttings in a fungicide solution as mentioned earlier. Even though Eucalyptus species are currently rooted vegetatively for forestry purposes, continued experimentation is required to improve propagation techniques.

Ficus sur

Ficus sur responded well to vegetative propagation. Cuttings are relatively easy to collect and prepare from fairly young trees, i.e. 6-10 years old. Sap flow from the cuttings was reduced by standing cuttings in water after they were cut. This procedure also kept the cuttings cool before they were planted.

Softwood to semi-hardwood cuttings of Ficus sur can successfully be taken during early-spring while hardwood cuttings are taken in late-summer or autumn. Hardwood cuttings are thus more difficult to root and are not recommended for commercial growing. See Table 2.4. Half mallet cuttings are preferred to straight stem cuttings. Because of the maturity of the older stem on the basal end of the cutting, rooting success has increased. See Tables 2.4 and 2.5. Cutting length should vary between 120 and 180 mm with at least two leaves per cutting.

This study showed that while cuttings can be taken as late as in winter, rooting will be retarded, i.e. only after 6-8 weeks. See Tables 2.4 and 2.5. These cuttings, however, will have to over-winter in a warm greenhouse to maintain their growth. Alternatively cuttings taken in early-spring will root faster, i.e. after four weeks and have sufficient time to establish by the end of summer. See Table 2.5. Ficus sur prefers relatively warm conditions, i.e. above 23°C and grow slower under cooler temperatures, i.e. below 11°C. Similar recommendations in Ficus spp. were reported by Hartmann et al. (1990). The present study showed that optimum greenhouse conditions provided during rooting strongly promote rooting performance, irrespective of treatments used for parent plants. See Tables 2.4 and 2.5.

Bottom heat should be available throughout the rooting period. See Table 2.6. Alternatively cold frame conditions will reduce rooting with less than half the success rate and double the rooting period. See Tables 2.4 and 2.5. A rooting medium of 1:1 peat and polystyrene is recommended for rooting success in Ficus sur.

Cuttings can be treated with No. 3 IBA powder before they are planted, however, for unknown reasons cuttings do not always respond well to rooting hormones. Rooting hormones do improve the rooting ability of Ficus sur and thus justify the additional expense and effort of using these chemicals.

In conclusion, the present observations suggest a maximal response of rooting for Ficus sur with 60 mm cuttings with two leaves, bottom heat, and No. 3 IBA powder. See Tables 2.5 and 2.6. Bottom heat will improve both quality and rate of rooting in cuttings harvested during summer.

Even though both conventional vegetative propagation and air layering techniques have been used to encourage rooting in stem cuttings of Ficus species (Poincelot, 1980), further research, possibly in vitro propagation, on Ficus sur is required. This will not only maximise production for commercial purposes, but will continue to maintain true genetic identity from selected parent plants.

Melia azedarach

Two options can be considered when selecting cutting material of Melia azedarach, i.e. thicker hardwood material as the plant is deciduous and cuttings can be made during winter dormancy, or soft semi-hardwood which can be collected during summer which is the vegetative growth season of the plant. Semi-hardwood cuttings, however, have the advantage of being collected over a longer period while thicker wood cuttings can only be collected in winter. It is also recommended that hardwood cuttings struck in autumn, must be taken at 4-6 weeks after leaf drop to encourage improved rooting success. See Table 2.7. Similar results were found by Toogood (1982) with hardwood cuttings taken during the dormant stage of plants. Further suggestions are that cuttings taken several weeks after leaf-fall will probably callus sooner than those taken earlier, although early-spring cuttings will also result in callusing. Hardwood cuttings may also be successful in late-winter when soil temperatures seldom drop below 0°C.

During this study, hardwood cuttings gave improved results over semi-hardwood. See Table 2.7. Hardwood cuttings of Melia azedarach are thus best taken during the dormant stage of mother plants. These cuttings do not perish easily and require no special treatment during rooting.

Hardwood internodal stem cuttings are more successful than those with remaining terminal shoots. See Table 2.7. The differences in rooting ability amongst semi-hardwood and hardwood cuttings are clearly shown in the higher survival rate of cuttings. See Table 2.8. Longer survival rates can be associated with higher rooting success. Hardwood truncheon cuttings measuring 300-600 mm will callus after six weeks whereas softer stem cuttings would not have developed signs of callusing at this stage.

High humidity levels, i.e. 70% in the greenhouse, will encourage dormant buds to develop without the formation of roots. See Table 2.7. These higher humidity levels will place cuttings under stress and the survival success of cuttings will be reduced. By shading the cuttings, the heat and light levels in the greenhouse may be reduced.

Cold frame conditions are preferred by Melia azedarach cuttings as bottom heat has little effect on improving the rooting success. See Table 2.7.

This study revealed that stems rot relatively easily and that treatments to prevent or cure rotting will enhance the callusing or rooting of cuttings. Cuttings dipped in boiling water for five seconds or sealed with paper glue will enhance callusing. See Tables 2.7 and 2.8.

Coarse (2-10 mm diameter), relatively sterile river sand appears to be the most successful rooting medium for callusing Melia azedarach cuttings. Secondly a 1:1 peat and polystyrene mixture provided sufficient moisture and aeration during the rooting process. See Table 2.7. The rooting medium for Melia azedarach must allow aeration and drainage of excess water, and at the same time retain sufficient moisture to sustain cuttings during the rooting process.

Apart from the extended survival rate of cuttings and the development of new growth, no evidence could be found on the effect of hormone treatments. See Table 2.7. Further research is required on the effect of rooting hormones on Melia azedarach cuttings. Janick (1986), however, reported that cuttings from naturally difficult-to-root plant species do not respond to auxin application. The transition from easy- to difficult-to-root is associated with the plant's change from juvenility to maturity. The formation of inhibitors at maturity can prevent the rooting of cuttings. He noted that difficult-to-root dormant cuttings become easy to root when leached in water to remove the inhibitors.

Future suggestions are to experiment with light conditions as cuttings require light in the greenhouse for synthesis of carbohydrates (Hartmann et al., 1990). Induction of rooting can be achieved by keeping deciduous hardwood cuttings in the dark (Janick, 1986). Thus root promotion can be achieved by using opaque greenhouse coverings or shading that etiolate the stem which affect the accumulation of auxins.

Vegetative propagation of Melia azedarach cannot as yet be considered a commercially viable method for nursery production. This study showed that cuttings cannot maintain a survival rate of more than 10 weeks in the rooting medium, thus, no positive results on rooting could be achieved. Based on these results further research is necessary to clarify the optimal conditions for the rooting of cuttings to ensure that the vegetative propagation of Melia azedarach is commercially viable.

Olea europaea subsp. africana

Cuttings taken from various parent plants for this study proved that vegetative propagation of Olea europaea subsp. africana is successful on selected plants. This factor is due to differences in genetic make-up which occur mainly from seeded parent plants (Hartmann et. al., 1990).

Small cuttings taken during spring from young vigorous growth tips after maturation gave improved results over harder wood cuttings. See Tables 2.9 and 2.10. Plants tend to retain much of their juvenility and will continue to re-shoot with relatively long vegetative shoots which are suitable for stem cuttings. Short heel cuttings, 7-12 cm, will start rooting within 10 weeks from planting. These heel cuttings are more successful than longer mallet cuttings. See Table 2.9.

Even though Olea europaea subsp. africana is usually propagated by stem cuttings, selected cultivars may also be propagated by bud-grafting (Hartmann et. al., 1990). Vegetative propagation can also be achieved through leafy cuttings (Poincelot, 1980).

The present study proved that tip cuttings, 5 cm long with 4-5 leaves, will root within four weeks. These cuttings should, however, be taken during spring and treated with No.2 IBA rooting powder. See Table 2.10.

The rooting success of cuttings decreased rapidly from mid-summer to early-winter as active growth of Olea europaea subsp. africana slowed down when flowering and fruiting started. See Fig. 2.2. Cuttings taken during mid-winter are the most successful and will root within four weeks. See Table 2.11. Cuttings taken in early- to mid-summer under high humidity conditions will also give good results. See Fig 2.1.

Results showed that a 70% humidity level with intermisting irrigation is required to induce root formation. Too wet conditions, however, will retard root formation.

Wounding increased root biomass by 60% under heated conditions, thus, wounding will expose larger cambium layers which will optimize the rooting area. For this reason heel cuttings will give an increase in root biomass over straight stem cuttings.

Even though bottom heat increased the root biomass of Olea europaea subsp. africana cuttings, it had no effect on the rooting success. See Table 2.10. A similar result was obtained by Hartmann et. al. (1990) who revealed that Olea species rooted much faster under continual heating, while root numbers and the root length from stem cuttings increased. In agreement, bottom heat considerably increased root biomass. See Table 2.10. Although no effect was noted on the rooting success, the significantly greater biomass and reduced time required for rooting due to heating suggested this treatment would be valuable for enhancing vegetative propagation of Olea europaea subsp. africana.

Soaking basal ends of mallet cuttings in IBA solutions improved the rooting success of Olea europaea subsp. africana, however, interactions of soaking with no bottom heat or wounding were not significant. See Table 2.9.

Coarse (2-10 mm diameter), relatively sterile river sand is a successful rooting medium, but requires relatively frequent watering. If the rooting medium becomes too dry, cuttings will be placed under further stress. Drainage and aeration of the medium were essential to prevent rotting of cuttings.

Until recently Olea europaea subsp. africana has mainly been used as rootstocks for propagation of edible Olea europaea (Hartmann et al., 1990). These seedlings are uniform in growth and provide excellent rootstocks for grafting purposes. Due to the propagation time involved and improvements in vegetative propagation techniques, Olea europaea is now successfully propagated by means of stem cuttings (Hartmann et al., 1990). These advancements in vegetative propagation can be applied on Olea europaea subsp. africana for vegetative propagation purposes. Future research should aim at developing techniques which will ensure rapid rooting and increased production numbers. To follow this route further work is required, probably on in vitro propagation of Olea europaea subsp. africana.

Podocarpus falcatus

No publications relevant to this study were available. This study, however, showed that Podocarpus falcatus can be propagated vegetatively from softer tip cuttings in late-summer to early-winter. See Tables 2.12 and 2.13. Either tip or stem cuttings can be taken after juvenile growth has matured. Straight stem cuttings were more successful than mallet or heel cuttings. See Table 2.12. The length of cuttings did not effect the rooting period. However, cutting lengths of 100-200 mm are recommended. See Table 2.13.

Cuttings should not be disturbed in the rooting medium until they are well rooted. The rooting period can vary from 6-8 weeks. See Tables 2.12 and 2.13.

Cuttings can be rooted in coarse (2-10 mm diameter), relatively sterile river sand under mist irrigation. River sand is preferred to bark, polystyrene or peat moss as it improves drainage and aeration during rooting and can be used with bottom heat, where cuttings are planted directly into the bed.

Bottom heat causes cuttings to root rapidly with less obstruction to good root formation than those which are rooted in cold frames. See Table 2.12. Wounding of stem cuttings improves root mass for Podocarpus falcatus, however, this treatment is further enhanced with the combination of bottom heat.

A rooting hormone treatment of 2% is recommended, however, cuttings responded better to No. 2 IBA powder than to a liquid treatment. Podocarpus falcatus cuttings can be planted in single containers and kept under mist spray for two weeks until they have hardened off.

As the rooting of Podocarpus falcatus stems are not commercially viable at present, further experimentation is required to improve the vegetative propagation techniques for this species.

Another suggestion would be to undertake trials to establish the feasibility of producing Podocarpus falcatus through in vitro propagation.

Syzigium cordatum

No published work was available for scrutiny during this study. However, this study proved that vegetative propagation of Syzigium cordatum is highly successful and suitable for commercial production.

Cuttings may either be from one or two-year-old wood or, semi-hardwood cuttings from the current season's growth. The latter, however, gave better results. These results demonstrate that root formation in cuttings of Syzigium cordatum is influenced by juvenile growth in parent plants, and that optimal response with respect to rooting performance of cuttings is achieved at maturation of growth, as observed in other plant species, e.g. Olea europaea subsp. africana.

Cuttings consisting of a heel from mature cambium layers were more successful than straight stem cuttings. See Table 2.14. Semi-hardwood cuttings, which are taken at the end of winter and towards the beginning of spring, are thus recommended. During this time Syzigium cordatum starts to grow actively, and consequently roots sooner than cuttings taken at the end of summer.

Cutting length should be about 150 mm, however, shorter tip cuttings (50-100 mm) will develop improved root systems and stronger plants. Leaves should be removed from the lower half of each cutting, and then dipped into No.1 or No.2 IBA powder. Wounding should be done to expose cambium layers to encourage rooting, however, using heel cuttings will improve the root mass.

The bottom third of the cuttings should be inserted into relatively sterile river sand (2-10 mm diameter) with overhead misting and bottom heat and then left for about six weeks to root while maintaining 70% humidity and a greenhouse temperature of 21-27°C. Maintaining bottom heat (21-23°C) in the propagation bed improves the rooting success of Syzigium cordatum compared to cuttings planted in the cold frame.

Rooted cuttings should be planted singly into containers and hardened-off under shade.

The relatively high rooting success (see Table 2.15) obtained with cuttings harvested from juvenile nursery stock has great implications for future nursery production of Syzigium cordatum. At such high rooting percentages, cuttings are less costly to produce and might even be rooted directly in the production container, reducing transplant failure and production losses, and yielding better quality material. It is therefore recommended that vegetative propagation of Syzigium cordatum be encouraged and applied in propagation nurseries for future propagation of sterile trees.

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