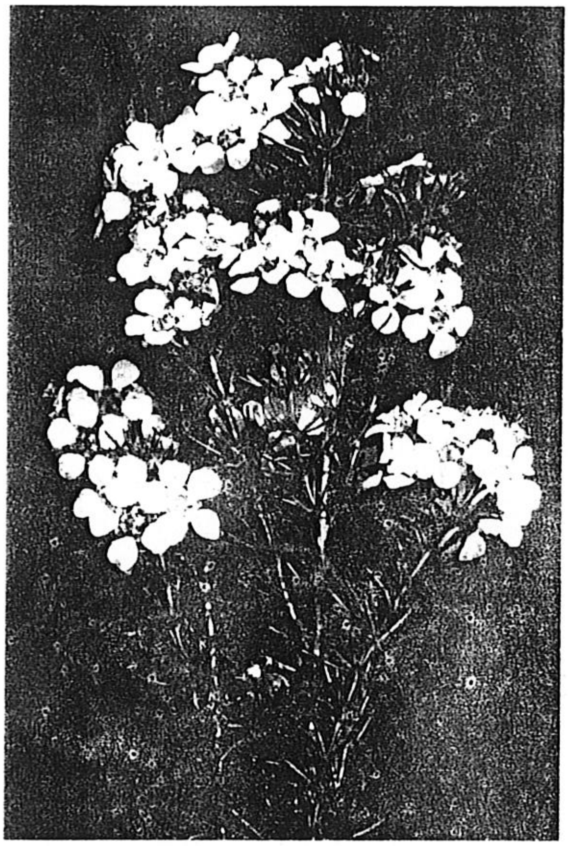
Assessment of *Astartea* sp. for Floriculture and Conservation



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Abstract

The *Astartea sp.* is an obligate seeder that only occurs on granite outcrops of specific topography where they can not be frequently burnt by fire. The *Astartea sp.* has specific physiological and morphological adaptations that allow it to survive in shallow soil pockets not suitable for growth of most surrounding vegetation. Frequent cool bushfires suit the conservation of this species rather than infrequent hot burns. Seeds germinated on tissue paper with deionised water had poor germination rates (<13 %). Smoke water (Kings Park and Botanic Gardens) applied to seed in petri dishes improved germination percentage. Germination was affected by temperature with maximum germination occurring between 5^0 and 15^0C. Tip cuttings taken from 1 to 2 year old parent material in mid January or June treated with 8 gL^{-1} indole butyric acid and struck in a peat:perlite (1:1) media gave the best rooting results. High mortality rates occurred after transplanting so cuttings should be struck in tubes so as to avoid transplanting. Placing cuttings in a fogging propagation system improved rooting percentage and reduced the incidence of root disease. This *Astartea* .sp shows considerable potential as a landscape or pot plant however it's use as a cut flower crop requires improved postharvest treatments or the selection of strains which exhibit longer vase life.

INTRODUCTION

Astartea sp. is an open, woody perennial shrub to 3.5 m high with lime green foliage and white to pale pink flowers. It grows on several large isolated granite outcrops north of Walpole in pockets of acid soil which support a heath community. *In situ* observations of *Astartea* sp. indicate considerable horticultural potential as a floral filler, pot and landscape plant. This rare taxon is currently classified as Priority 2 Flora.

The first collections of this species were made by Conservation and Land Management (CALM) botanists and volunteers in 1994. Since then there has been considerable interest by CALM staff to examine the horticultural potential of this plant. To date this taxon has not been officially taxonomically described and has been broadly classed into the *Astartea. fascicularis* complex by CALM botanists. The plant morphology, habitat, and distribution are significantly different to the *A. fascicularis* but for management reasons it will stay within this complex until further taxonomic description is completed.

In January 1997 a licence was granted for the collection of material from the field. A comprehensive check for this species in the nursery industry, Perth herbarium and numerous text were unsuccessful. There are a number of factors that may have contributed to the lack of commercial development of this taxon. The most apparent would be physical isolation and limited population number and it's very recent recording. The collections made by CALM represent the only herbarium samples for this taxon.

For successful commercialisation of a plant species reference needs to be made to the environmental factors that govern its existence in its natural habitat. To understand the ecology of this species and why it exists solely on these granitic habitats reference needs to be made to the environmental variables that exist in the surrounding forest and compare them with the variables experienced on granite outcrops. Identification and examination of significant differences will help in elucidating the ecology of this *Astartea* species. An attempt will be made to identify possible reasons why this species exists solely on a limited number of large granite outcrops.

Particular emphasis is made on the role that fire plays in the moulding of the flora of the south west and the role it may play in the ecology of this *Astartea* species. Previous fire regimes, as practised by the Aborigines, have placed particular selection pressure on the native flora, often resulting in plant species becoming endemic to particular habitats such as granite outcrops.

This study partially assesses the floricultural potential of the *Astartea* sp. Given the time frame of this study it is not viable to complete a comprehensive assessment. When working on a plant from such a unique habitat where little or no information exists for this species, the research questions are numerous. Commercial potential is largely dependent on development of an efficient propagation system. Development of propagation techniques, both sexual and vegetative and suitable postharvest treatments are imperative if the full commercial potential is to be reached. Further more the conservation status of this species could be dramatically improved if it were introduced into commercial production.

By firstly examining species ecology we can further determine the propagation and growth requirements of this *Astartea* species and aid in the development of a conservation strategy for this *Astartea*.

Literature Review

Western Australia has many beautiful flowering shrubs that have considerable horticultural potential in amenity plantings, pot culture and cut flower production. To date only a few for example Geralton wax and Kangaroo paws have been successfully commercially exploited. The south west of Western Australia has a very diverse range of flora, many of which show considerable potential for horticulture but remain undeveloped or obscure. This Astartea sp. has only recently been recorded and has not been described but has potential for use in horticulture. Its soft dense foliage and prolific white to pink flowering display make it an ideal amenity or pot plant and its late flowering season create an opportunity for export as cut flowering stems.

Potential Markets

The Australian Myrtaceae have a number of genera which exhibit the required characteristics of commercial cut flowers: a combination of floral display, stem length, and vase life. *Chamelaucium* and *Thryptomene* are the most commonly known members of this family used as cut flowers. Floral fillers from the Myrtaceae such as Geralton wax and *Thryptomene* are Australia's largest export flower crops. Native Australian fresh cut flowers have considerable export potential with over $ 23 million currently exported, most of this being from W.A (Karingal Consultants 1994). A wide variety of native species are currently exported to markets around the world.

In the hybridisation within the genus verticordias desirable characters of individual species are combined to enhance the floricultural potential. Consideration of these characters gives an indication of a species potential for cut flower development. The characters of greatest consideration in selection of parental species include (McGuire, 1989): flower colour, size and form, inflorescence structure, plant habit and yield, flowering season, disease resistance, post-harvest life.

Traditionally Western Australia's wild flower industry has developed on exports of wild flowers cut from natural stands however the major trend now is for cultivation of many of these species. The cutting of natural stands of this

Astartea sp. is not possible due to conservation status therefore the development of this plant for commercial industry is heavily dependent on cultivation.

The pot plant industry is worth a billion dollars annually in Australia (Considine, pers. comm.). There is great potential for developing Australian plants for flowering pot culture particularly for some of the overseas markets. In the past there have been few Australian native plants that have featured among the successful promotions seen in this industry. The promotion of the Boronia 'Heaven Scent' in Victoria is an exception, with 100 000 plants sold in 3 weeks (Peate, 1994).

It is possible that many of West Ausrtalia's wild flowers could be marketed in the form of compact pot plants. Examples of these are the Geralton wax and *Verticordia* spp. These plants produce masses of strikingly coloured flowers that have a ready market overseas. Genotypes with compact growth habit are desirable however with the use of chemical growth regulators to reduce the rate of stem elongation, increase branching and induce flowering, it is possible to produce plants which will compete strongly with the traditional potted flowering ornamentals (Reid, 1984). The *Astartea* genus is poorly represented in the nursery industry. Currently there are only a few species of *Astartea* sold in the nursery industry. The most prominent species is *A. fascicularis,* which is widely used as a landscape shrub.

Flowering pot plants are becoming more desirable as they have a number of advantages over cut flowers. The flowers last longer as they remain on the living plant, a number of flowering displays can be achieved from the one plant, and the plant can be re-used the following year or alternatively used as a landscape plant after the current flowering has finished. Issues for the development of a plant for flowering pot culture include: propagation and cultivation, indoor flowering life, growth manipulation, flower induction, and breeding (Slater, 1989).

Botanical Description

Astartea sp. is an open shrub growing to a height of 3.5m. It is densely branched, with leaves opposite or closely arranged in opposite leaf bundles of 12 to 18 on the stem giving a soft, dense foliage character. The leaves are linear, 6-14 mm long, 0.4-0.5 mm wide, glandular, light green turning red under prolonged water stress. Leaf colour, morphology, and arrangement on the stem make a very attractive foliage. Flowers are solitary, born in the axils of leaves with 1 to 2 flowers per leaf bundle. Flowers are white to pink, 8-15 mm wide with 5 sepals, 5 petals 3-5 mm long, 2.5-4 mm wide. Capsule is light green, 3-4 mm across with peduncles 6-10 mm extending the flowers out from leaf bundles (CALM, 1997). The multiple branches and numerous flowering sites on the stem result in an attractive floristic display, either as single stems or plant as a whole. Flowering occurs between October to December and varies between and within populations. This creates potential for a niche market after peak *Chamelaucium* production.

Habitat and Distribution

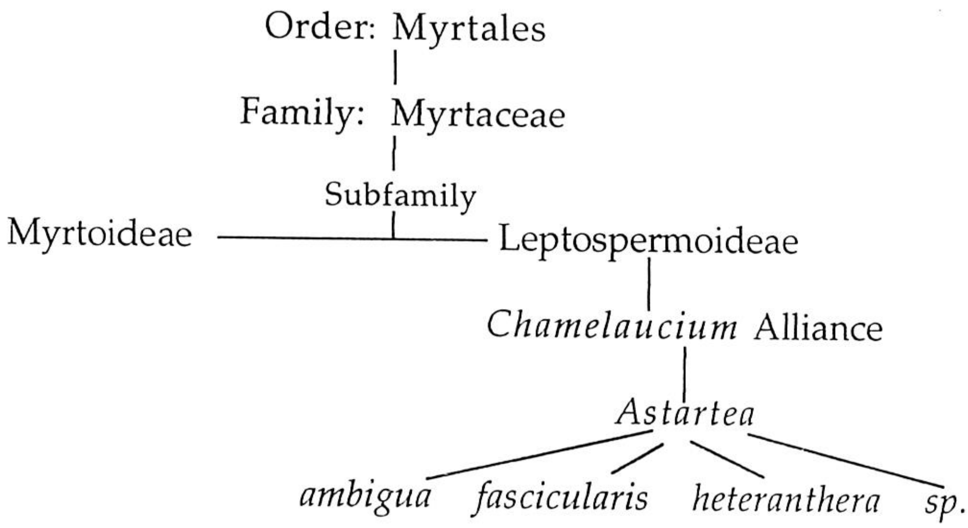
Astartea sp. has been recorded from an area north of Walpole, east of the South West Highway, WA. Grows in pockets of sandy loam on large granite outcrops. Granite underlies the soil of much of the surrounding area, which is covered by tall open forest dominated by karri (*Eucalyptus diversicolor*) and jarrah (*Eucalyptus marginata*). Much of the landscape is dotted with large granite outcrops which predominate the top of ridges and hills and were presumably left after the original soils eroded away over time (Groves, 1994). The vegetation on these outcrops are subject to a Mediterranean climate but experience much larger extremes in temperature and water relations. The geographical isolation and the niche growing conditions result in islands of vegetation with some species or genetic lines not represented anywhere else but on these outcrops including *Astartea* sp. The cracks and depressions that occur across the granite gradually collect soil that supports a heath community. Some of the taxa found in these communities include: *Pimelea imbricata, Cryptostylis ovata, Verticordia plumosa, Acacia myrtifolia, Acacia triptycha* and *Andersonia sprengeloides.* The dominant species include: *Astartea* sp., *Chamelaucium forrestii, Agonis linearifolia, Eutaxia obovata,*

Status

Astartea sp. was first collected in 1994 by staff from Conservation and Land Management (CALM), Manjimup . It was recollected in 1995. To date it has been placed in the *A. fascicularis* complex of species. The current conservation status is Priority 2 Flora. Priority 2 Flora are species inadequately surveyed and known from 1 to 5 populations in the wild, at least one of these on a nature reserve or national park. Despite 30 granite outcrops visited across the region, by a CALM volunteer, this taxon has very recently been recorded on only 8 occasions. It would appear to be rare, rather than poorly collected (Hearn, pers. comm.). With a better understanding of the ecology and taxonomy and 8 recorded populations may lead to removal of this species from the Priority 2 listing to Priority 3.

Taxanomic Grouping

"Astartea sp. is within the *Chamelaucium* alliance of Myrtaceae"



Biodiversity

Biodiversity within the species is an important issue for this taxon due to the small size and number of populations and their geographical isolation from each other. The issue of biodiversity in this study is primarily concerned with the genomic and morphological diversity within the taxon and within populations and the ramifications for conservation and development for horticulture. This *Astartea* sp. is known from 8 isolated populations. The genetic diversity between and within populations is unknown.

Environmental stresses may severely reduce the number of plants in a breeding community. When there are low numbers of plants the gene pool becomes permanently reduced. This event is often referred to as a "bottleneck" (Hearn, pers. comm.). The consequence of these events is the loss of species diversity and therefore a reduction in a species ability to survive changes in it's environment. In small isolated populations this may culminate in local extinctions.

Minimum viable population size can be defined as that which will maintain genetic diversity, be capable of adaptive evolution and also long term survival (Moran and Hopper 1987). Determining the minimum viable population size for the *Astartea* sp. is crucial for the development of long term conservation strategies. To counteract the effect of inbreeding it has been proposed a minimum of 50 individuals are required in a population and for long term survival 500 (Frankel and Soule, 1981). Current estimates of population size by CALM are in the order of 40 to 1000. However, without information on the evolutionary history of these populations it is not possible to draw any conclusion on the long term survival of this species. For example population size may fluctuate and this would affect the gene pool (Moran and Hopper, 1987).

Breeding systems with self incompatibility are widespread in many Myrtaceous species and is often stigmatic or stylar incompatibility. These systems have evolved to generate outbreeding (James, 1981). The existence of such systems becomes particularly relevant when dealing with a small gene pool, such as could be expected in populations of this *Astartea* sp. It is not known if this *Astartea* sp. is capable of self pollination. The pollination vector for this *Astartea* sp. is also unknown.

The unknown genetic diversity of this species of *Astartea* should be considered in assessing it's use in horticulture. A lack of species diversity within this taxon may severely limit the potential for breeding new varieties and may affect the "fitness" of this plant when grown outside the range of conditions under which the species evolved. The occurrence of genetically isolated populations increases the possibility of breeding new varieties by combining the biodiversity into one gene pool. Possibilities exist for intraspecific hybridisation within the Chamelaucium alliance if genetic separation is not to great. This has been achieved with other genera and species of this alliance (Yan, pers. comm.).

Fire Ecology

The season of fires, their periodicity and intensity in an area may play an important part in regulating the abundance or rarity of species. It is therefore the most significant selective agent in the evolution of life histories of many species (Brown *et al.*, 1993). Fire plays an integral role in moulding the karri bushland that surrounds the granite outcrops which host the *Astartea* sp. What is not fully understood is the role of fire on the granite vegetation. Fire may play a significant role in shaping the ecology of *Astartea* sp. or possibly a derivative of fire, such as smoke.

The high fire incidence which has prevailed in the south-west for many thousands of years left very few species which can not cope with a regime of frequent fires. Some plant communities such as swamps and granite outcrops burn infrequently and many seldom catch alight even when the forest around them is in flames (Christensen, 1992).

For 40,000 years aborigines occupied this region and imposed fire regimes in the south-west ecosystems. They used fire extensively to clear land, hunting and other reasons. These practices may not exist today but the influence of these practices in shaping the forest ecosystems are extensive (Christensen, 1992). Fire has obviously been a factor in shaping the present communities, and it will need to be taken into account to develop an understanding of the significance of this *Astartea* sp. on these granite environments. Examination of past and present influences of fire in these communities may prove important for the conservation of such species. The intensity and duration of a fire determines the degree of damage to the vegetation. This is affected by fuel loading of the forest and the environmental conditions during and prior to the fire. Fires are often classified as cool or hot burns. Cools burns are less destructive on the vegetation and often occur in spring or late autumn or in vegetation with low fuel loading ie. frequently burnt. Hot fires usually result from heavy fuel loads and in months when the understorey is dry.

The advent of Europeans has led to significant changes in fire regimes. Fires seem to have become less frequent, but more intense and cover larger areas (Busby and Brown, 1994). The affect of these changes needs examination. The small frequent fires experienced under aboriginal occupancy have changed to large more damaging fires. It is these larger fires which may have the most devastating effect on the granite outcrops, resulting in complete scorching of all vegetation. Aboriginal burning practices have eliminated most fire sensitive species from frequently burnt areas. Sensitive species are restricted to areas not frequently burnt. The susceptibility of these outcrops to fire is unknown. Furthermore the sensitivity of this *Astartea* sp. to fire is unknown. To both conserve and commercialise this species an understanding of the role of fire is required.

Fire Syndromes

Species can be grouped into syndromes related to their successful adaptation to environmental stresses such as fire that have occurred over the plant's evolutionary history. Fire ephemerals are short-lived plant species that occur following fire and usually complete their life cycle before the next fire.

The frequency of fires alters species diversity, with low frequency resulting in a loss of re-seeding species. Seeders are further characterised by seed size. Some species produce fewer large seed better suited to shaded habitats, while others produce large numbers of small seed which saturate the post fire environment. These small seeds are probably best suited to more open sites with less competition (Mott and Groves, 1981). Resprouters are not killed by severe fires and resprout from epicormic buds protected under the bark of trunks, lignotubers or other underground tissue (Bell et al, 1993). These species regenerate quickly after a fire and tend to channel less energy into seed production than seeders. Seeders and resprouters have contrasting root and shoot morphologies which allow them to co-exist in the post fire environment (Bell *et al,* 1993). The fire response of Western Australias Myrtaceae species falls into two groups, the seeders and the resprouters. Seeder species are killed by intense fire and rely on establishing seedlings in the post-fire environment for species survival. The life syndrome of the *Astartea* sp. is not known.

Sexual Propagation

Seed

Seed is the cheapest way to produce a large number of plants. It produces plants with a natural morphology of fully formed root systems which are better able to cope with extremes of climate which may occur in low management systems of flower production or amenity settings. The disadvantages are that species may be variable when grown from seed, and due to juvenile effects flower production may take some time (Colwill, 1982). It is these issues which must be addressed if the most efficient method of propagation is to be found. This *Astartea* sp. produces large numbers of seeds even from on the one plant. This high seed production may prove to be the basis of the most efficient method of propagating this species with minimal damage to the population.

Viabilty

Many species of W.A natives do not have sufficient photosynthetic reserves to complete reproductive processes resulting in seeds that are not fully developed. This is particularly prevalent in species which annually release seed. Limited water availability may reduce the proportion of viable seed. This often occurs in shallow rooted shrubs that develop during late spring and early summer. The *Astartea* sp. suits this criteria. Seed inviability may also result from inbreeding. Plant species which have a high level of self computability often produce a large proportion of inviable seed. It is probable that genetic factors acting late in seed development contribute to inviability of seed in numerous Australian inbreeding species (Bell *et al,* 1993).

Dormancy

In seeds of most species, internal controls exist or develop during ripening and for a period of time after harvest that prevent germination. These mechanisms prevent seed from germinating in adverse conditions (Hartmann, 1990). Many Western Australian plants hold their seed on the plant and release them when conditions are favourable often after an environmental cue such as fire. Other species shed their seed soon after maturity. The often harsh environment that these seeds are shed exposes seeds to conditions normally considered unfavourable for long term seed survival. These include fluctuations in temperature and water, predation, microbial degradation, and fire. It is for these reasons that many of Western Australian plants are dormant when shed from the plant (Plummer and Bell, 1996). While seed dormancy plays an important role in plant ecology and survival, it can be a major problem for propagators. The particular cue for germination of a species relates to the environmental processes from which it has evolved, particularly in a Mediterranean environment. Determining the dormancy mechanism of the *Astartea* sp. will not only aid in commercial propagation but will help in the development of a successful conservation strategy for the long term survival of this species. There are many mechanisms that impose seed dormancy, the accumulation of chemical inhibitors in the fruit or seed tissue and the modification of seed coverings. Seed coats can inhibit germination by preventing penetration of water and oxygen, supplying chemical growth inhibitors or may elicit mechanical constraint.

Seed Coat

Hard seededness is a common adaptation in habitats prone to fire in Australia (Bell *et al,* 1993). These seed may contain both viable embryo and endosperm but have very low germination. In the Leguminoseae the outer seed coat hardens becoming suberised and impervious to water. Cells of the outer integument become integrated, incorporating suberin and develop an external covering of cutin (Hartmann, 1991). Further restriction can be imposed by mechanical constraint as found in *Acacia* and *Personia* . Treatments found to break seed coat dormancy are numerous and species dependant. Heat shock, exposure to boiling water, mechanical scarification and acid treatments result in increased germination percentages of hard seeded species (Mott and Groves, 1981).

Seed dormancy in *Thryptomene calycina* is imposed mainly by the action of the seed coat acting as a barrier to water uptake. Beardsell (1993B) determined that germination of this species was significantly improved by nicking the seed coat or briefly washing with sulphuric acid. Some species of *Baekea, Kunzea* and *Leptospermum* and other species of the Chamelaucium alliance release seed annually. They rely on dormancy mechanisms in the seed to prevent premature germination (Beardsell et al. 1993A).

Seed coats may have soluble growth inhibitors which must be denatured or removed for successful germination. Some are degraded by heat, such as from a fire or boiling. This can be seen in the differences in germination of seed treated by heat where 82% germinate compared to 30% following stratification(Bell *et al,* 1993). Both treatments break hardseededness but only heat releases seed from dormancy. Boiling and acid treatments are also believed to leach inhibitors from the seed coat (Beardsell et al., 1993A).

The development of woody nuts and fruit of the Myrtaceae is an adaption to its harsh environment. These woody capsules contain several to many viable seeds that are dispersed after an environmental cue, for example, fire.

Smoke

The recent discovery that smoke stimulated germination of the rare South African plant *Audounia capitata* (De Lange and Boucher 1990) has led to the exploration of benefits for germination of many Australian flora (Dixon *et al.* 1995). Smoke treatment ensures a much greater efficiency when propagating from seed and this should make more species available for horticulture (Broun *et al,* 1993).

The study of Dixon et al. (1995) found that smoke applied in a variety of ways stimulated germination of many Australian species both *in situ* and *ex situ*. The importance of smoke as a cue for germination was established in a wide range of species with often exceptional improvements in germination. Five myrtaceous species showed a positive response. This *Astartea* sp. was not examined in that study and any promotive effects of smoke for this genus are unknown.

Smoke applied directly to the seed or the soil surface *in situ* and *ex situ* stimulated germination in a wide variety of Australian species. This was applied as crude smoke or in a liquefied form (Brown, 1993; Dixon *et al,* 1995).

Smoke is important for germination (Dixon and Roche, 1996) it can promote earlier and more uniform germination *ex situ*. and enables germination in species previously difficult or impossible to germinate by conventional means or had low levels of germination. The promotive effect of smoke is independent of seed size and shape and plant life form but is likely to be a related to life history syndromes. Aerosol smoke, smoke dissolved in water or direct smoked solids (activated clays, sand particles) or direct smoked seeds are effective methods for delivery of smoke for germination however, high doses of smoke water can inhibit germination in many species. These germination response can change over time with species responding at different rates and to differing levels over the germination period (Dixon and Roche, 1996).

Smoke germination response has been achieved with seed that has previously required boiling, nicking of the seed coat, heat treatment or exposure to charcoal eluates (Dixon et al., 1995). The promotive substance of smoke is still under investigation although possible links have been made with the high ammonia content of smoke and the promotive effect of ammonia on the germination of *Erica hebecalyx.*

The soluble nature of the smoke compounds allows smoke to be applied as smoke water. This method involves the bubbling of smoke through water. Treatment of seeds with the resulting solution has proved very successful and the most convenient both *in* and *ex situ.* Kings Park and Botanic Gardens recommended that a 1 in 10 dilution is sufficient to germinate many native seeds soaked for 24 hours.

Germination

Seed germination is a critical process in the ecology of species from this Mediterranean climate. Germination is defined by Mott and Groves (1981) as the process commencing with imbibition of the seed and the establishment of metabolism in its rehydrated tissues, and ending with the protrusion of the embryonic root or shoot through the seed coat or testa.

Germination of seed is dependant on both external and internal factors. Three basic external factors are required include oxygen, water and temperature. In addition many W.A species require light, smoke or heat shock. Metabolic processes begin to occur when the seed imbibes water and the enzymes begin to utilise the stored food reserves. Respiration in the seed may be entirely anaerobic until the seed coat is ruptured (Raven *et al,* 1992). Although many species germinate over a wide temperature range it is usually related to periods of rain fall such as winter in south western Australia.

Ants

Some plant species use ants to help bury their seed. This occurs with seeds which have a specialised ant attractant food bodies called an elaiosome. Seed is collected, the food body removed and the seed discarded in middens in the nest (Buckley, 1982). Often removal of the food body or environment changes associated with burial, release seed from dormancy, protect seed from fire or provide better conditions for germination or seedling establishment. Plants which have their seed dispersed by ants are referred to as myrmecochorous.

There are numerous examples of Australian myrmecochorous species particularly within the genus *Acacia*.

In a study of the seed removal from the floor of a jarrah forest, that insects (presumably ants) removed only the smallest seed (<0.02g) while vertebrates tended to take the heavier seed (Abbott *et al.* 1985). Grevilleas from the Sydney region have two ecological syndromes for seed dispersal. Species that lack an elaisome are not moved by ants, those which do are moved by ants. The removal of seed to the ants nest may reduce the impact of seed predators (Auld, 1994). Removal of the pericarp tissue of *Lomandra* seed was required for successful germination. Ants were observed to disperse and consume this pericarp tissue (Crawford, et al., 1994)

Vegetative Propagation

The development process required to introduce a new species as a floricultural crop includes a successful propagation system. Some of the previously mentioned disadvantages of sexual propagation can be over come by vegetative propagation. This is where a plant is asexually reproduced through the regeneration of plant organs to produce a plant identical in genotype to the parent. The advantages of this method are, uniformity of usually selected superior genotypes, speed of propagation including bypassing seed dormancy and the juvenile non-flowering period. For these vegetative propagation is commonly used in the nursery industry.

Clonal production results in genetically identical plants. The disadvantage of this is susceptibility to pests, diseases or other environmental hazards, which often occur in revegetation and rehabilitation exercises. This often results in an increase in vulnerability to new pests or where a cultivar is introduced into a new environment where conditions and pests occur that did not occur in the original growing area. This is particularly pertinent for the commercial production of this *Astartea* . Its growing environment is likely to be vastly different to its natural habitat. The advantage of genetically isolated clones for commercial production is the uniformity of yield and the potential to clone desirable plant characteristics. For example Chamelaucium uncinatum `Purple Pride' was propagated from a single plant and is now distributed world wide. It may be possible that viruses and diseases are transferred from the parent plant, therefore attention should be paid to the selection of suitable parents and hygiene practices.

The techniques for vegetative propagation are numerous and include: layering, division, grafting, budding and cuttings. The particular technique used is highly dependent upon the species however the most commonly used is that of stem cuttings.

Propagation is possible because all living plant cells contain genetic information and theoretically the capacity to reproduce the whole plant. This is called totipotency (Hartmann, 1990). The second fundamental characteristic of plant cells that enables them to propagate vegetatively is dedifferentiation. This refers to the capacity of differentiated cells to return to a meristematatic condition and develop a new growing point. Species and tissues differ in their ability to undergo regenerative processes resulting from the differentiation of meristematic cells. Success of vegetative propagation often relies on manipulation to provide the optimal conditions for plant regeneration. A variety of plant tissues can be used including roots, stems, buds or leaves. Stem cuttings are the most commonly used for woody perennials because these already have a shoot and bud system established and need only develop a root system.

Root Formation

Adventitious roots arise from any plant part other than by the normal development of roots in seedlings. There are two types of adventitious roots: preformed and wound roots. Preformed roots develop naturally from vascular cambium tissue in the stem of the parent plant. Wound roots are of particular interest because they develop only after the stem is severed from the parent. Wound healing response is the precursor for the initiation of adventitious roots (Hartmann, 1990).

The formation of wound roots can be divided into four stages (Davies, 1988). The first stage is the dedifferentiation or remeristemation of differentiated cells usually near the vascular cambium. Second is the formation of root initials near vascular bundles or vascular tissue. Root primordia are then formed which then grow and emerge outward through the stem tissue and connect with the vascular tissue within the cutting. The precise location where adventitious roots originate varies between plant species. In woody perennials such as *Verticordia* and *Thryptomene* root development in stem cuttings is usually from living parenchyma cells, primarily in the young, secondary phloem, but may also arise from vascular rays, cambium, phloem, lenticels or the pith (Lovel and White, 1986). The time required for primordia to initiate and emerge varies greatly within and between species and is reliant on biochemical and anatomical features of the plant.

Callus is an irregular mass of parenchyma cells in various stages of lignification that occurs at the basal end of cuttings under favourable environmental conditions. The formation of callus and roots often occurs simultaneously but are usually independent of each other. In some species however, callus formation is a precursor for root development (Hartmann, 1990).

Wounding the base of cuttings can promote root production on stem cuttings. This can be achieved by the stripping of leaves or vertical cuts with a sharp instrument. This technique can increase water absorption from the media and improve the absorption of exogenously applied hormones. It may also increase the sites for root initiation (Mac Donald, 1986). Wounding may act as a sink for metabolites, rooting cofactors and auxins which promote root production (Davies, 1988).

Hormones

The treatment of cuttings with hormones and plant growth regulators has become a standard practice for the promotion of root formation on cuttings. Difficulties with the propagation of many woody Australian plants has been overcome with the application of growth regulators. These include auxins, cytokinins, gibberellins and ethylene. Out of all the growth regulators, auxins have the greatest effect on root formation in cuttings (Hartmann, 1990). A common naturally occurring auxin in plants is indolacetic acid (IAA). Auxin in plants are believed responsible for apical dominance and other plant activities such as stem growth, leaf abscission and activation of cambial cells. When applied exogenously to the base of cuttings auxins cause the cells to dedifferentiate and form adventitious roots. Auxins stimulate growth by increasing the extensibility of cell walls. The mechanism controlling this function has not yet been determined. Two suggestions are that auxin activates an enzyme that drops cell pH resulting in the loosening of cell wall structure. A second hypothesis is that auxin activates specific genes that change the synthesis of cell walls allowing them to be more elastic (Raven et al., 1992).

Indolebutyric acid (IBA) is a synthetic auxin which is commonly applied to cuttings to stimulate root production. Other commercially available auxins include napththaleneacetic acid (NAA) and indolacetic acid (IAA) but it is not as common. These auxins can be applied as powder formulations, dilute solutions, concentrated solutions, and gel formulations. IBA and NAA are more effective than IAA for the promotion of adventitious roots (Hartmann, 1990). Micro organisms and sunlight can rapidly breakdown IAA. Blazich (1988) found that metabolic processes of the plant can conjugate IAA with other compounds or destroy it, reducing its concentration. This suggests it is not suitable for commercial use. IBA and NAA are not as easily degraded during storage, but should still be kept out of direct sunlight.

Dawson and King (1994) IBA is the most effective auxin in the promotion of roots on a range of Australian woody plants. This includes numerous genus from within the Myrtaceae, Lamiaceae, Thymelaeaceae family such as *Verticordia, Chamelaucium, Pimelia* and the *Astartea fascicularis* . Increases in root number, length and improved rooting percentage of *Chamelaucium uncinatum* were achieved when cuttings were treated with short duration dips in ethanolic solutions of IBA. The best response of the range tested was achieved at a concentration of 4 g/L of IBA in solution, the lower 2 cm of stem immersed for 40s to achieve 90% rooting. Only using this treatment was axeamined*Astartea fascicularis* and achieved 83% rooting (Dawson and King ,1994).

Age of Parent

Cutting material forms roots more readily when taken from young than more mature plants. Juvenility refers to the biological age of tissue not chronological age the plant. Juvenility can be maintained by practices that encourage stem rejuvenation such as pruning in *Chamelaucium* and coppicing of *Eucalypts* (Dixon, 1994). The reasons for this are varied and not fully understood. Rooting inhibitors have been found associated with the difficult to root *Eucalyptus deglupta* and *E. grandis* . The adult tissue contained a higher concentration of compounds that blocked the formation of adventitious roots (Paton *et al,* 1970). Phenols are secondary compounds manufactured by the plant and are thought to act as auxin cofactors or synergists in root initiation . The production of phenols reduces with increasing age of the plant. The enzymes or enzyme activators in the plant may be the limiting factors (Hartmann, 1990). The degree of lignification of stem tissue increases with age of parent and this could also act as a mechanical barrier to root formation.

Carbon and Mineral Nutrition

Carbohydrates are important in rooting because they are the building blocks of complex macromolecules, structural elements, and energy sources. Vigorous root growth in cuttings has been attributed to high carbohydrate levels (Mac Donald, 1986). Nitrogen is required in nucleic acid and protein synthesis and it has been found to be negatively correlated with adventitious root formation (Hambrick et al., 1985). It is thought to be one of the biggest influences on rooting (Hartmann, 1990). A balance needs to be achieved between the level of carbohydrate and nitrogen in the cutting tissue. This is referred to as the C/N ratio and will differ for each species. It would be expected that the *Astartea* would have the highest carbohydrate and lowest nitrogen levels in summer when it is at its most dormant.

Mineral nutrients play a role in the development of adventitious roots. Elements such as N, P, K, Ca, Zn, Mn and B are required for root growth and development (Blazich and Wright, 1979). Zinc is required for the synthesis of endogenous auxin. High concentration of manganese can deactivate exogenous auxins in stem tissue (Davies, 1988). Boron enhances root development by increasing the uptake of exogenous auxins and by mobilising plant growth regulators necessary for rooting (Davies, 1988). The mineral composition and requirements of *Astartea* sp. are unknown. Determining the fertility of soil pockets which support this plant may give an indication of its' nutrient status.

Time of Year

The season in which cuttings are taken can play an important role in root formation. With most species there is an optimal period of the year for rooting. For commercial purposes the time taken for cuttings to form roots, establish and time for planting in the field should be considered in relation to the best times to take cutting material. The optimum time to take cuttings is related to plant physiology which is a combination of genome and environment (Hartmann, 1990). During the year Myrtaceae species have different rates of growth The degree of influence of a number of factors mentioned previously change during the year. This includes carbohydrate levels, amount of lignification, endogenous hormones / inhibitors and leaf number (Carter and Slee, 1992). For a number of Australian woody natives more success is achieved when cuttings are taken after a flush of growth. Dawson and King (1994) found soft and semi-hardwood *C. uncinatum* cuttings rooted at greater than 90%.

Through out the year the *Astartea* is expected to experience significant water and temperature extremes. Adaptive stress mechanisms of the plant may play a role in the time of year optimal rooting is achieved.

Therapeutic Factors

C. uncinatum is propagated successfully from 4-10 cm of tip stem cuttings with the bottom 2 cm of stem is dipped in auxin. Optimal results are achieved in a mist propagator with bottom heat applied (Manning, Considine and Growns, 1996). Dawson and King (1994) applied these same techniques to *Astartea fascicularis* and achieved 83% rooting within six weeks using a mix of equal parts peat, perlite and vermiculite.

Rooting media should be kept moist at all times during propagation. The air filled porosity of the media will vary with species, but traditionally it was thought to be best at around 25-30% (Handreck and Black, 1994). This allows for diffusion of oxygen to the base of cuttings necessary for respiration. The composition of a propagating mix should match the type of watering system used and the susceptibility of the plant material to disease.

Protectant or systemic fungicides can be used to combat fungal disease but excess use may cause toxicities in the plant. Growool® a rockwool product has been used with good success for the propagation of *C. uncinatum* using clear propagating hoods (Newell, 1997).

Misting and Fogging facilities are commonly used for propagation and differ in the size of the water droplet they produce. Misting facilities produce droplets between 70 and 100 microns in size where fogging facilities produce droplets in the range of 10 to 30 microns (Gordon, 1995). Fogging systems have a higher humidity and leach less nutrients from the cutting material than the misting facility (Davies, 1988).

Bottom heating of cuttings has been found to be beneficial with rooting media temperatures for temperate species maintained in the range of 18 to 25^{0}C (Hartmann, 1990).

Postharvest

The flowering nature of this *Astartea* sp. is similar to a number of other native crops used as floral fillers, they include the *Chamelaucium, Baekea* and *Thryptomene*. Some *Baekea. spp* have vase lives of only a few days. This can be dramatically improved by appropriate post harvest handling treatments such as using flower preservatives, recutting stems and regular water changes (Beardsell, 1989). Pulsing of flowering stems with sucrose is an established postharvest treatment used for many exotic cut flowers. Its benefits include longer storage and vase life, increased opening of buds and improved flower colour and size. Carter et. al in 1989 examined the response of a number of native cut flowers to sucrose pulsing. They found that no benefit was gained in pulsing Geralton Wax or *Leucadendron*. Similar results could be expected for the *Astartea*.

The soft petals of the *Astartea* sp. are likely to be susceptible to postharvest handling. A close relative, the *Astartea. fascicularis* has an established vase life of 5 days (Beardsell,1989). A number of cut flower species of Myrtaceae produce ethylene. Ethylene production can cause severe reduction in vase life. Ethylene induced flower abscission has been documented in *Chamelaucium* and *Verticordia*. The vase life of ethylene sensitive species can be significantly lengthened by pulsing stems with silver thiosulphate (STS) (Joyce, 1993). It is unknown whether the buds of this Astartea. sp will continue to open after harvest or whether this species is ethylene sensitive. Vase life can vary considerably within a species and allows scope for selection of clones from within a species that exhibit desirable vase life. This has been successfully carried out by the Victorian Department of Agriculture for the improvement of *Baekea. behrii* (Slater 1996).

Materials and Methods

Field Observations

Photographs and numerous field observations were taken over the period of the year examining aspects of species ecology and distribution. These included: response of this species and co habitating vegetation to fire, habitat conditions, in situ growth rates, seeding and flowering type, intra and interspecific variation.

Seed Collection

Seed was collected on 10 January 1997 from a single population. Three to four branches were excised from individual plants containing dehiscing fruit and placed in individually labelled, brown paper bags. Branches from 8 plants were collected and bag one containing 10 branches from separate plants from across the entire granite outcrop. Branches were stored at 20 ^{0}C for one month before the seed was removed. Seed was cleaned using a fine sieve, and seed were stored in sealed plastic containers and stored at room temperature.

Seed Germination Trial

The effect of a range of temperatures on germination was examined. Four squares of Wettex® sponge, cut into 2 cm squares were placed evenly under one sheet of 70 mm Whatman No. 1 filter paper in each of 20 petri-dishes. With an 8 ml solution containing Previcur® (1% v/v) in deionised water (D.I) was added to each petri-dish. Using a pipette or dropper place approximately 5 ml into each petri-dish and allow sponge and filter paper to soak. Draw off most excess water pooling in the dish before approximately 100 seeds were placed in the centre of each wet filter paper and dishes were sealed with paraffin tape. Each temperature had 3 replicate dishes. Seeds were incubated in a range of temperatures (5,10, 15, 20, 25, 30, 35 ^{0}C) in the dark. Seed germination was observed weekly using a dissecting microscope. At this time dishes were topped up with 1% Previcur®.

Smoke Treatment of Seeds

The effect of smoke water on *Astartea* sp. seed germination was examined.
This experiment uses the same technique as described for the previous seed germination trial, where seeds will be germinated in petri-dishes. Seven

concentrations of commercial smoke water were used (0, 0.3, 1, 3, 10, 30 and 100 %). Commercial smoke water (Kings Park and Botanic Gardens) was diluted with (D.I) water. To surface sterilise, dry seeds were placed in the centre of the untreated filter paper and 4-5 drops of 3 % Previcur ® was added. This ensured surface sterilisation of the seed with minimal effect on the concentration of the treatments. The Previcur ® solution was evaporated in air for 5 minutes. Once dry the seeds were spread over the filter paper. There were 100 seeds in each petri- dish 3 replicates per treatment. Seeds were incubated at 15^{0}C. therefore all treatments will be maintained at 15^{0}C. Germination was recorded weekly under a dissecting microscope. Fine droplets of fungicide were sprayed on filter paper when fungal contamination occurred.

In situ Smoke Water Seed Germination

In situ seed germination was examined at Mt. Johnson. An area of moss covered soil that contained recently dead *Astartea* sp. plants but not other vegetation was used. The moss appears to act as mulch and seedlings could only be found in moss covered soil. The presence of the old *Astartea* sp. indicated sufficient soil depth for growth of seedlings and the high probability of an *Astartea* sp. seed bank. Two unvegetated 1 square metre sites were pegged out with fluorescent plastic tape then divided into 4 equal quadrants (50 x 50 cm). No *Astartea* sp. seedlings were found within these quadrants. Smoke water solution (250 ml of 10%) was applied evenly over 2 randomly allocated quadrants in each site. The next rainfall event was recorded the following day. The site was isolated with difficult access and germination was recorded once after 2 months. Germination was recorded for each quadrant.

Collection of Plant Material

Plant material was collected during the middle of the day on 10 January from Mt. Johnson. Thirty centimetre plant stems were placed in two sealed 90 mm plastic pipes, which had been capped and contained 250 ml of cool water. After 4 hours transport and refrigeration at 5^{0}C for three days this material was used for the first propagation trial.

On 20 February plant material was collected from Granite Peak population. Plant material was placed in plastic bags for 3 hours of transport prior to refrigeration at

$50^{0}C$ for 3 days.

The third set of plant material was collected on 11 June from Mt. Johnson. This material was collected using the same technique as described for January 10. Included was the foliage and flowering stems used in the postharvest trial. The 6 foliage stems were cut to approximately 40 cm immediately before being placed in the tubes. This reduced the chance of possible air embolisms in the xylem. The flowering stems were cut to approximately 30 cm long before transport in the tubes.

Vegetative Propagation

Plant material was cut to 5-7 cm, and cuttings divided into tip and basal cuttings, which had indole butyric acid (IBA) 3 gL^{-1} hormone gel (Purple clonex ®) applied unless otherwise stated. Tip cuttings were the first 5-7 cm of stem section containing the shoot apex, basal cuttings refers to the rest of the stem tissue. All plants were treated once a week with a rotating fungicide treatment regime of Benlate®, Rovral® and Fungarid® (1 g/L). Leaves were removed from the lower third of the cutting. Cuttings were placed in a media of peat and perlite (grade 500) in the ratio (1:1) in seedling trays. Strike rate (+/- roots) and cutting mortality rates measured weekly. Replicates were placed in separate trays and standard errors calculated.

The effect of exogenous indole butyric acid (IBA) hormone concentration on rooting percentage was examined. Ten tip and ten basal cuttings, with 2 replicates, taken in February were dipped in 2 concentrations of IBA gel formulation (Clonex®, Growth Technology, Fremantle) 3 $g.L^{-1}$ (purple) and 8 $g.L^{-1}$ (Red). Up to the bottom 2 cm of the cutting was dipped in the gel. The control was no hormone application. A clear plastic, vented propagation hood was placed over seedling trays and cuttings watered every 2 days.

The effect of different compositions of potting mix on rooting percentage was examined. Ten tip and ten basal cuttings, with 2 replicates, taken in February were placed in 5 treatments of propagating media. Media comprised peat and perlite in the following ratios: 1:1, 2:1, 1:2, 100 % peat and 100 % perlite. A clear plastic, vented propagation hood was placed over seedling trays and cuttings watered every 2 days.

The effect of age of parent plant on the rooting percentage was examined. The age of plants were estimated on size of plant. Stems from 1, 2 and 3 year old plants were excised. Ten tip and ten basal cuttings, with 2 replicates, taken in February were planted for each of the 3 years. A clear plastic, vented propagation hood was placed over seedling trays and cuttings watered every 2 days. The age of parent material can only be estimated without accurate knowledge of relative growth rates. The ages of parent plants used in this experiment were estimated from size in relation to the growth rates observed from several other sites.

The effect of time of year that cuttings are excised was examined. Ten tip and ten basal cuttings, with 2 replicates, taken in February were planted for each of the 3 times of the year: mid January, February and June. A clear plastic, vented propagation hood was placed over seedling trays from February and cuttings watered every 2 days. Cuttings taken in January were kept in the misting room. Cutting material was placed in the fogging chamber.

The difference in rooting percentage within the same population was examined. Six 20 cm stems were excised from random parents in three isolated sites approximately than 100 m from each other. Forty tip and basal cuttings were made from these six stems taken in February and treated as mentioned previous. A clear plastic, vented propagation hood was placed over seedling trays and cuttings watered every 2 days. Two reps of 40 cuttings of *Chamelaucium uncinatum* 'Purple Pride' was used as a control.

Growth conditions

Once roots were established on the cutting material they were carefully removed from the striking media and potted into small propagating tubes containing Macroblend® (Yates, Milpera N.S.W.) potting mix. Tubes were placed within seedling trays and covered by a clear plastic propagating hood (vent remained open). All trays remained in the non irrigated section of the glasshouse. Plants were drenched in fungicide in the same rotation as above and also with Thrive® (Yates, Milpera N.S.W.)

Postharvest of Flowers

Flowering stems were found on a single plant from Mt. Johnson. This plant was a mature specimen approximately 3m tall and it appeared to have been flowering for several weeks prior to collection, as indicated by the presence of freshly dehisced seed capsules. The flowering display was not as spectacular as in November and December, with only the terminal 5 cm of branches producing flowers. However, these flowering stems may give a basic guide to the postharvest life of *Astartea* sp.

Stems (30 cm), were immediately placed in D.I water and transported to the lab (48 hrs). On June 13 the terminal 10 cm of each flowering stem was excised and immediately placed in treatment vials. There were only 7 flowering tips so only one treatment of Sodium dichloroisocyanurate (DICA) solution at 30 mg L^{-1} was applied to all tips. The basal 5 cm of foliage was stripped of leaves before the tips were placed into small plastic vials containing 30 mg.L-1 of DICA solution and were kept in the constant temperature room. To follow senescence, a hedonic scale was developed (Fig.17). The hedonic characters for each tip were recorded at 2 day intervals for a period of 22 days. Five days after the commencement of the first trail it was observed that flower buds continued to develop and open on the stem tips. The remaining plant material which bore immature buds were placed in D.I water. within the constant temperature room . Their development was also recorded every 2 days.

Postharvest hedonic flowering scale:

1)Compact bud - compact bud sunken (no visible petals) and contained within 2 bracteoles. Central rib of bracteole is lime green, fading to opaque at fringes of bract. Bract tip pointed and lime green. Size (mean width across bracteole): 3 mm

2) Star shaped bud - central rib and spike of bracteole; yellowing. Calyx lobes bright green and raised above bracteoles. Calyx lobes, condensed, star shaped and raised above flattened condensed light pink petals. Size (mean width): 3.6 mm

3) Domed bud - bracteoles absiced, bright green calyx lobes level with unopened flattened dome of pink petals. Size (mean width) : 4.3 mm

4) Balloon- calyx lobes yellowing and spreading as petals enlarge to become higher than calyx lobes by 1 to 2 mm. Corolla bud swollen and raised, first petal becoming released from tight bud. Size (mean width) : 4.4 mm

5) Petals Open - calyx lobes yellowing with a slight red ring appearing below calyx lobes. Petals fully open and pale pink. Petals slightly recurved on margins. Anthers brown; filaments - pale pink; style - yellow, green. Size (mean width): 14.2 mm

6) Petals Senescing - petals paling to off-white,pale brown. Petals,stamens and style shrivelling. Size (mean width): 9.5 mm

7) No Petals - calyx lobes,stamens and style senesced (brown). Calyx dark green. Petals absisced. Size (mean width): 4.95 mm

Postharvest of foliage

Stems were collected on 11 June and stored in the constant temperature room in D.I water 2 days prior. Stem tips (15) were cut to 15 cm. The bottom 5 cm of leaves were removed from both apical and basal stem cuttings. Five of each of the stem type were placed into D.I water and 10 into 30 mg dichloroisocyanurate (DICA) solution. A hedonic scale was developed to follow senescence. Plants were observed at day seven and every two days there after until day 28. The hedonic scale for foliage to senescence is as follows:

1) Slight wilting of the tip of soft shoots
2) Slight shrivelling of the leaves
3) Slight wilting of leaves
4) Loss of leaf lustre and lighter colour
5) Yellowing of leaves at the base of stem
6) Leaf drop at the base of stem

In Situ Growth Measurements

On 11 June 1997, 10 juvenile (approx. 45 cm tall) and 10 seedling (approx. 15 cm tall) plants were tagged and there individual heights were recorded. These plants were remeasured on 16 October and the relative growth rate in height assessed.

Absolute and relative growth rates were calculated.

Soil analysis

Soil samples were analysed by CSBP Soil Analysis laboratories. The limited quantity of soil and the delicate nature of the sites meant only small samples of approximately 200 mls were taken. Two samples were taken from Johnson block population in January 1997 and 3 samples were obtained from Peak block population. Each sample was removed from the site from which cutting material had been taken. Samples were obtained by scrapping off the moss layer before removing a plug of soil and placing it in a sealed clean plastic container. The CSBP soil analysis examined the following soil properties: organic carbon, pH, conductivity, N, P, K, Sulphur and Iron. The summary of soil analysis methods used are given (Appendix A). Soil pH and outcrop run off water was measured in June 1997, at Johnson block population.

Results

Population Distribution and Numbers

Known distributions of *Astartea* sp. have been established by field searches conducted by botanists from CALM, Rare flora volunteer and the author. All specimens were identified by CALM botanists from Manjimup. Of the 30 outcrops searched, positive identification of collections have been made from only 8 outcrops. Two specimens collected from other sites have been identified as separate species of *Astartea.* The average area of the outcrops that support this species is 5.08 ha with the smallest rock measuring in total is 0.75 ha and the largest 10 ha. The area of granite outcrops known to support this species totals 41 ha. Numerous granite outcrops within this size range occur within the area of known distribution (Fig. 1), but they do not support *Astartea.* sp. It appears that outcrop size alone does not determine the presence of this species, rather it is a combination of factors. Populations were described as the total number of *Astartea* sp. occurring on the same outcrop. Sub-population refers to the pockets of isolated plants that were scattered across the outcrop.

Climate

The region experiences a Mediterranean climate with warm summers, mild winters and an occasional frost. The micro climate of the elevated outcrops would include high ambient temperatures. In Western Australia temperatures during winter decrease with increasing distance from the sea. Summer temperatures are affected more by latitude and less by proximity to the coast. The known populations only occur in areas of 1000 mm or greater annual rainfall. The closest population is 25 km from the south coast (Fig. 1). Most rain falls in winter (May to Oct.), however limited summer rainfall is experienced across the known distribution area. Heavy dew is common throughout the year and may provide some run-off water to the pockets of soil on these granite outcrops.

Ecology

Fire

Fire appears to be one of the determining factors that controls the ecology of *Astartea* sp. on these outcrops. Observations on all known sites suggested that

areas of the granite outcrops that were subject to fire did not support *Astartea* sp. Areas of the granite with cracks or shallow basins that were subject to fire were dominated by resprouter species, such as *Agonis linearifolia* (Fig. 2).
The dominant outcrop species include: *Astartea* sp., *Chamelaucium forrestii*, (reseeders) and *Agonis linearifolia, Eutaxia obovata* (resprouters).

Outcrop Topography
The size and shape of the granite outcrop determines it's vulnerability to fire and scorch from fire in the neighbouring vegetation. A high fuel level will result in more heated air passing over the outcrop. In the situation of a very hot burn around a granite outcrop, it is likely that fire or hot air would burn or scorch these outcrops and kill all vegetation. The unique features of the outcrops that support *Astartea* were identified:

1) The outcrop must be large enough to ensure sufficient distance exists between the pockets of soil containing the *Astartea* and the surrounding forest. This would provide a physical barrier and protection from fire or it's heat.

2) Soil pockets must be large enough to support the life cycle of the *Astartea* over several seasons. Soil depth is important for the survival of mature seed bearing plants. Shallow soils dry out much quicker and would not support plants to maturity.

3) Soil pockets must have sufficient water catchments and storage capacity to ensure plants can survive the hot, dry summer months.

4) All outcrops are elevated in relation to the surrounding landscape ranging by 1 m to 40 m. All known population habitats occur between 180 m and 220 m above sea level.

The colour plates (Fig. 3) documents fire ecology of the Mt. Johnson population. The fire accessible areas of the outcrop (plates: a, b) are dominated by resprouters, mostly Agonis *linearifolia* , and areas where fire is not accessible, except if a hot burn, the *Astartea* sp. dominates (plates c, d).

Morphological Changes Through The Year

Morphological changes in the plant were observed through the year. These were expected to be the result of environment stress, in particular water deficits and heat stress. In the summer months plants were observed to have significant reddening of the leaves and many of the basal leaves were shed, presumably due to water stress. In summer, leaves appeared to have more pronounced oil glands and a very distinct scent.

Diversity

Different plant morphology was observed *in situ* (Fig. 6). Distinct variations in plant forms were observed within each population. Figure (7) shows two morphologically different *Astartea sp.* stems. Stem (a) has 4 branches and longer internode length than stem (b) which had 15 branches smaller leaves and a higher flowering density from a 25 cm stem. Further diversity was observed in flowering times between and within populations from October to December. Variations in flower colour, white to darker pinks were frequent.

Pollination

During *in situ* flowering numerous insects were observed to visit the open flowers. These included ants, native wasps and the honey bee. Flowers of *Astartea* sp. produce a sugary nectar on which the ants and other insects appeared to feed.

Germination Strategy

An examination of burnt forest surrounding several *Astartea* sp. habitats indicated that this plant was an obligate seeder. It is killed by fire and heat scorch and does not develop a lignotuber or have insulating bark. It does not resprout after fire from either above or below ground tissue.

Growth Rates

Seedlings, approximately 15 cm tall, had a higher relative growth rate (0.004 mm / day) than juvenile plants, approximately 45 cm tall, (0.0031 mm / day).
Juvenile plants had a higher absolute growth rate (Table 1). Figure (8). documents the growth rate of an immature sub-population.

Table (1) shows the height of seedlings and juvenile plants over a period of 120 days. It does not represent total growth including branching.

Growth	Stage	
	Seedling	Juvenile
Absolute Growth Rate		
mm/day	0.83	1.67
mm/week	5.8	11.7
Relative Growth Rate		
mm/mm/day	0.004	0.0031
mm/mm/week	0.028	0.022

Evenly Sized Sub Populations

Across all sites examined, the individual pockets of soil supporting mature *Astartea* sp. plants contained no seedlings (Fig. 4). It is assumed that all the plants of similar size appeared to be of similar age. The stage of maturity of plants appeared to be uniform within each sub-population (plants in separate pockets). However, across an outcrop sub-population ranged from 4 m high to small seedlings < 30 cm (Fig. 4 & 8a.). *Astartea* sp. skeletons of similar size were present within each of the sub populations (Fig. 5). These skeletons represent the previous generation within each of the soil pockets. They show no sign of death from fire but rather a process of natural senescence, which most likely occurs during water stress over summer. These soil pockets have a limited supply of water and nutrients. It appears that an entire sub population can be lost over the summer months as available soil water is depleted.

Astartea sp. plants produce very large numbers of seed. It is expected even after predation that the soil seed bank will be high. Even at low germination rates plant densities will therefore be high. The plant density across populations varied from about 25 mature plants/m^2 to only 1 or 2 plants? m^2.

Soil Description

The soil environment in which the taxon occurs would be considered inadequate for most angiosperms to complete their life cycle. The soil appears to be unique to these granite outcrops and the shallow pockets that support the *Astartea* sp. are rarely deeper than 15 cm and support some growth when they are as shallow as 5 cm. A thick layer of mosses (approx. 2-5 cm) covers much of the granite, including the soil pockets. It is expected that this acts as a mulch, reducing water loss and moderating temperature extremes. It may also play a role in reducing soil erosion. The pockets of soil experience extremes in abiotic conditions. Temperature and water supply are the most obvious. The large body of granite rock heats and cools much slower than ambient air and it is therefore expected that day / night temperatures of the soil pockets would lag behind that of ambient air. The crack and basins where the *Astartea* sp. is found are supported by water run-off from large surfaces of granite that act as catchments. Even light showers can cause pockets of soil to become waterlogged. It is expected that even heavy dew can provide the soil with small but significant quantities of water. During winter the soil remains permanently waterlogged. The soil water in the summer months is expected to be very limiting. It was not determined whether the *Astartea* sp. roots form a mycorrhizal association.

Parameter	**Site 1** (n=2)	**Site 2** (n=3)	**karri forest**
Nitrate mg/kg	8.3+/-0.7	1+/-0	Total N
Ammonium mg/kg	1.3+/-0.3	15.5+/-3.7	(16+/-8)
Phosphorus mg/kg	20+/-0	12.5+/-1.2	<2
Potassium mg/kg	126+/-15	121.5+/-40	110+/-30
Sulphur mg/kg	16.4+/-4	12.1+/-4	n/a
Iron mg/kg	5.84+/-0.2	738+/-13	15+/-6
Organic carbon %	476+/-84	5,83+/-0	3.1
Conductivity ds/m	0.097+/-0	0.073+/- 0	0.07
pH ($CaCl_2$)	3.72+/-0.1	3.42+/-0.1	5.7
pH (1.5 water)	4.8+/-0.1	4.5+/-06.5	6.3

Table 2: Chemical analysis of soil from two sites on separate granite outcrops supporting *Astartea* sp. Analysis by CSBP laboratories, Bayswater, WA. Reference adapted from: `Reference soils of south-western Australia' W.M. McArthur

The chemical analysis suggest this soil is comparable in fertility to the native soils that support karri (*Eucalyptus. diversicolor*) and jarrah (*E. marginata*). The Concentrations of macro elements are similar, however the Iron level is significantly higher than surrounding native soil and pH is much lower. The soil salt concentration measured by conductivity, is very low, and organic matter content is higher than surrounding native soils (McArthur, 1991).

Run-off Water	**Soil on the**	**Soil at distances from base of outcrop.**		
from outcrop	**outcrop**	**10 m**	**20 m**	**40 m**
4.7 +/- 0.5	4.7+/- 0.6	5.0 +/- 0.3	5.2 +/- 0.77	6.2 +/- 0.2

Table 3: pH of soil from from Mt. Johnson outcrop and surrounding forest soil and samples of water contained in soil pockets (n=3).

Seed Biology

Seedcoat

Seed left on moist filter paper for a week imbibed water and the seed coat became soft and was easily damaged. The seed coat appeared to consist of a matrix of cells and was only several cells thick. A soft fleshly elaiosome was present on all seeds (Fig. 9a.).

Germination

The *Astartea* sp. seedlings exhibited epigeal germination with the seedcoat covering the small cotyledons during elongation of the hypocotyl (Fig. 9c, colour plates). Excision of imbibed seed showed that the internal tissue was an embryo consisting of a very condensed shoot. What appeared to be the radicle emerged first, however this was the hypocotyl. At the distal end of the hypocotyl was a domed structure form which the root later emerged (Fig. 9c.). No endosperm was present. There appeared to be an apparent line of weakness in the seed coat which split and allowed the shoot to emerge (Fig. 9b.).

* see p. 52

Germination was improved by smoke water and temperature. Figure (10) indicates that at low concentrations of 0.3 % dilution germination percentage increased by 68 % from non smoked seeds. Maximum germination of 78 +/- 3.2

% was achieved at 30 % dilution of smoke water. Germination rate was reduced to 42 +/- 4.1 % using full strength smoke water.

The temperature significantly affected germination rates of smoked and untreated seed (Fig. 11). Maximum germination rate for untreated seeds was 12.5 +/- 2.1 %. Maximum germination rate for smoked seeds was 77 +/- 5.6%. Decrease in germination occurred at temperatures higher than 15^{0}C. This was most pronounced in seeds treated with a 30 % dilution of smoke water. Maximum germination rate for both smoked and untreated seed was 15^{0}C. Peaks in germination rate occurred at 5^{0}C and 15^{0}C for both smoked and untreated seed.

In Situ Smoke Trial

There was no evidence of germination in either the control quadrats or those treated with smoke water. Examination of the soil surface after removal of the moss layer also showed no sign of *Astartea* sp. seed germination.

Vegetative Propagation

Time of Year

The cuttings taken in January and June attained maximum rooting after 4 weeks, while those taken in February took 3 months (Fig. 12). The parent plants form which the February cuttings were taken had the greatest degree of leaf drop and leaves remaining on the plant had become darker in colour many had turned red.

Age of Parent Plant

A decrease in rooting percentage of cuttings with increasing age of parent plant was observed (Fig. 13). Tip and basal cuttings taken from approximately one year old plants obtained a rooting percentage of 93 %. Cuttings taken from plants 3 years or more old only achieved a maximum of 60 % (tip) and 27 % (basal). The exact age of the parent plants may not be entirely accurate but a trend can be observed between rooting percentage and plant juvenility.

IBA Concentration

IBA application significantly improves the rooting percentage of tip cuttings taken in February (Fig. 14). Maximum rooting percentage was achieved using

8gL-1 IBA gel. Increasing IBA concentration did not have a significant effect on the number of basal cuttings producing roots.

Transplanting

The process of transplanting rooted cuttings from propagation media to pots for growing on, resulted in a very high mortality rate. All the rooted cuttings taken in January and February died within 4 weeks of being planted into tubes containing potting mix. Of the 120 cuttings planted into tubes only 3 survived. The third cutting trial involved no transplanting. Cuttings were struck directly into the tubes and after 2 months all cuttings that had formed roots survived. Cuttings that were potted into tube stock for growing on were fertilised with full strength Thrive® once weekly. All developed a chlorosis of leaves particularly at the actively growing trips. Two weeks after the application of full strength trace elements (Librel BMX®, Advanced Fertilisers) all yellowing of the leaves was corrected.

Propagating Media

The highest rooting percentage (50 %) was obtained in propagating media with a ratio of peat / perlite in the ratios (1:1) or (2:1). Cuttings taken in June were placed directly into premium potting mix to avoid the need for transplanting. After 3 weeks rooting percentages reached a maximum at 18% for tip and 50% for basal cuttings.

Propagation Media	Tip Cutting %	Basal Cutting %	Average %
Peat / perlite (1:1)	50	50	50
Peat / perlite (2:1)	60	40	50
Peat / perlite (1:2)	30	50	40
Peat (100%)	30	40	35
Perlite (100%)	0	10	5

Table 4: Percentage of cuttings with roots. Cuttings were taken in February and placed in different media in a mist propagating room.

Propagation Systems

Of the three propagation systems used the incidence of disease prior to transplanting was the highest in the misting room and lowest in the fogging system (Table 5). The propagation media remained drier in the fogging system than the misting. The incidence of root disease was reduced using the clear plastic propagating hoods and minimal when cuttings were placed in the fogging chamber.

System	% dead
Misting room	93 +/- 4
Plastic hoods	54 +/- 13
Fogging chamber	14 +/- 2

Table 5: Percentage of rooted cuttings senesced from disease in each of the propagating systems used.

Site Affects

A difference existed in rooting (%) between the 3 sites with the maximum 55% form site 2 (Fig. 16). Considerable error reduced the level of significance. The low strike rate of the Geralton wax indicates the method of propagation was not ideal (Fig. 15).

Post Harvest Physiology

Flowers

A preliminary guide to flower development and vase life was determined (Fig. 17). Immature flower buds continued development to senescence after shoots were excised from the plant. Due to a lack of replicates statistical analysis could not be carried out and, quantified analysis of the development process could not be given.

Foliage

Vase life of stems varied between apical and basal. Apical stems lasted for 18 days, basal only lasted 9 before half lost visual appearance. These results are expected to vary significantly with the time of year stems are tested.

1) Apical stems

The time for 50% of apical stems in DICA solution to lose there visual appearance was 18 days. In D.I water apical stems did not reach 50% senescence after 28 days.

2) Basal stems

The time for 50% of basal stems in DICA solution to lose there visual appearance was 9 days and 20 days in DI. water.

Figure 1. Geographical range of known *Astartea* sp. populations including rainfall pattern.

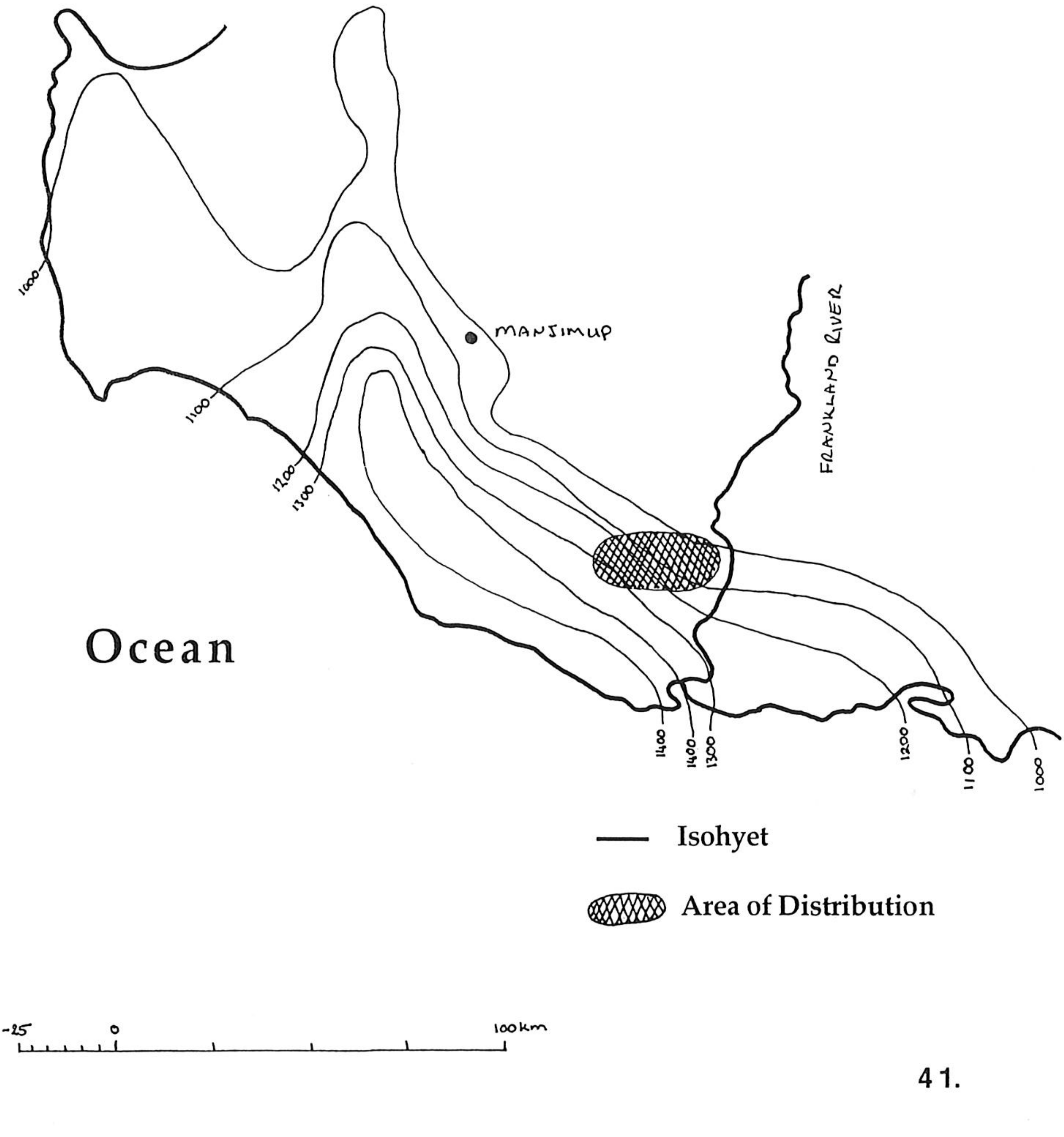
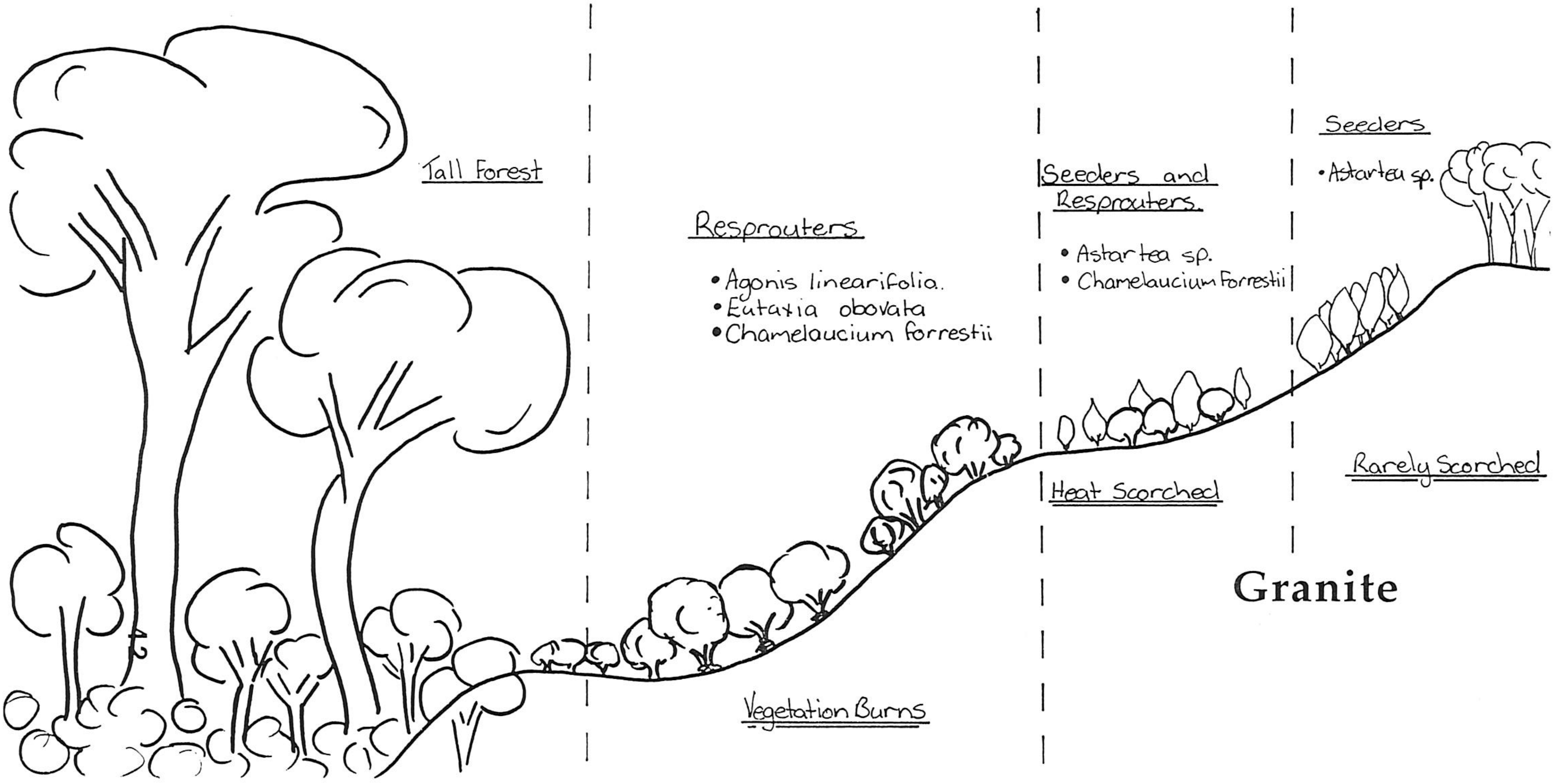


Figure 2. Typical vegetation profile of granite outcrops supporting *Astartea* sp. showing influence of fire.



A. B.

Figure 7. Two distinct morphological variations of flowering stems of *Astartea* sp. from the same population (actual size). Stem A. has 4 branches and stem B. has 16 branches.

Figure 10. Germination (%) of *Astartea* sp. in petri-dishes at different concentrations of smoke water incubated at 15^0C

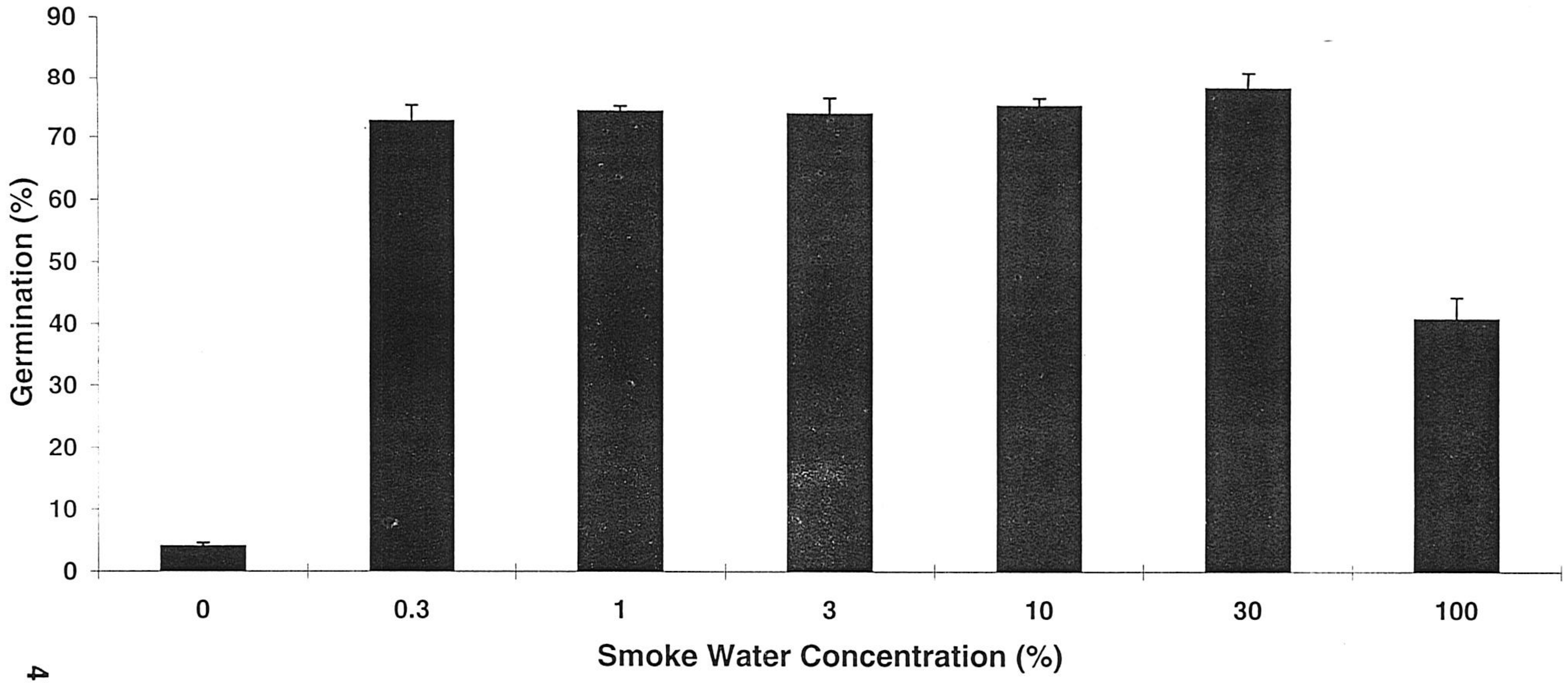


Figure 11. Comparitive germination (%) between smoked & non smoked seeds at different temperature treatments

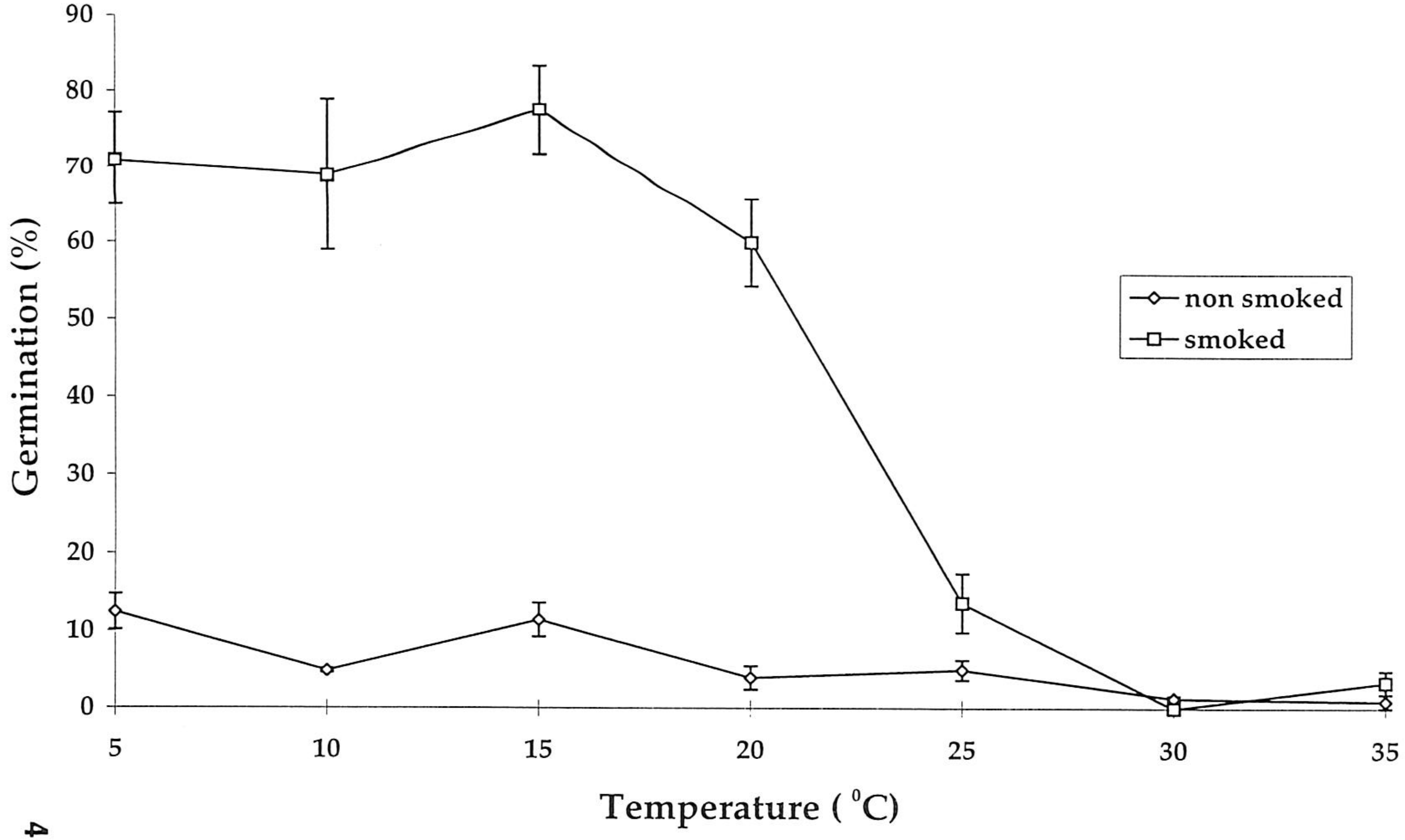


Figure 12. Changes in rooting (%) of Astartea sp. in peat / perlite (1:1) with different times of the year that material was taken

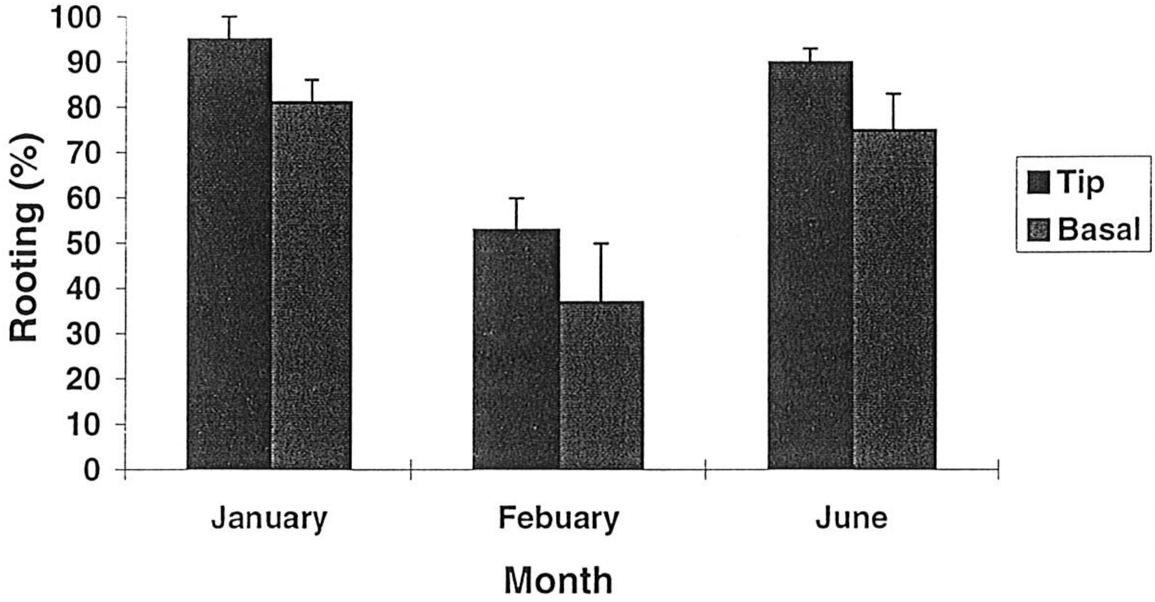


Figure 13. Changes in rooting (%) of *Astartea* sp. in peat / perlite (1:1) with different ages of parent plant taken from the same population on January 10, 1997

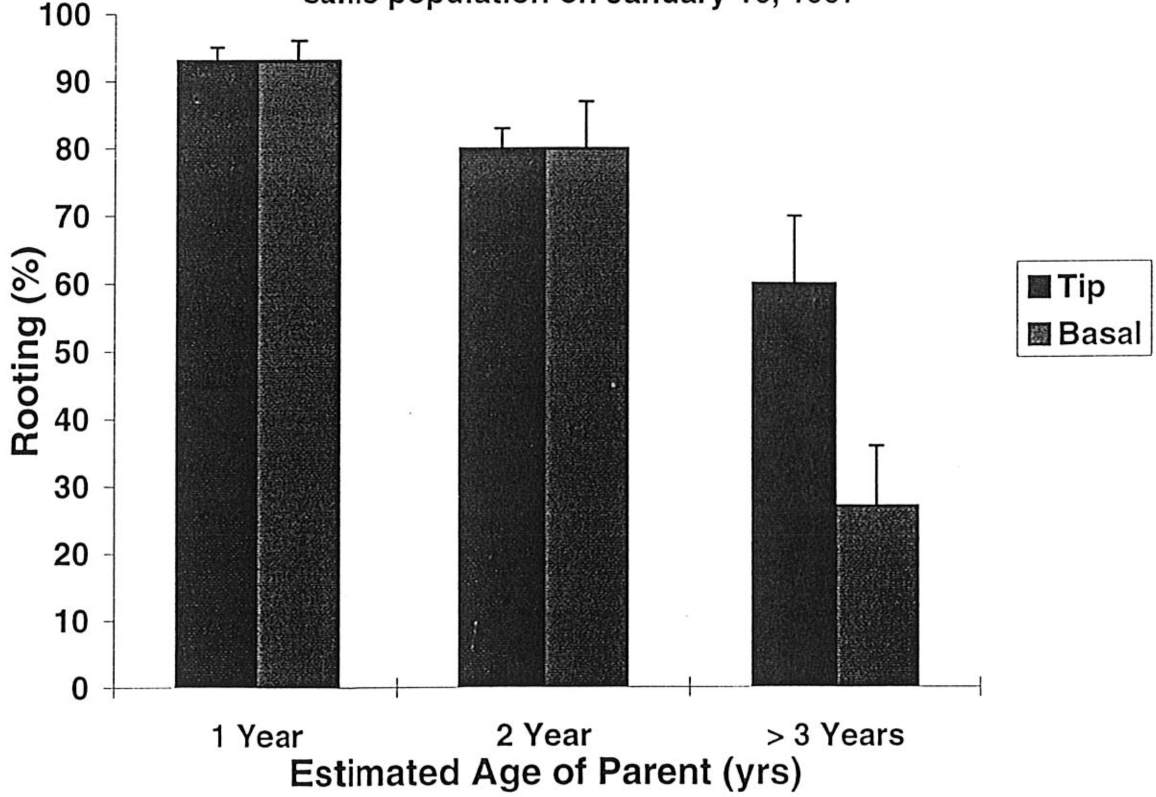


Figure 14. Changes in rooting (%) of *Astartea* sp. cuttings with different concentrations of IBA

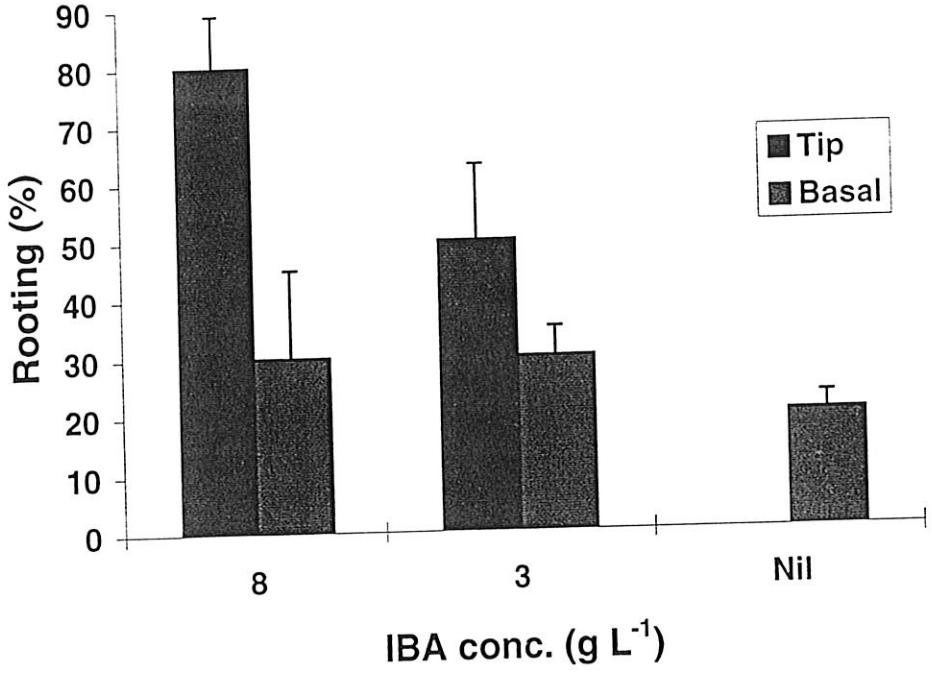


Figure 15. Changes in Rooting (%) of 3 sub-populations with Geralton wax as a control

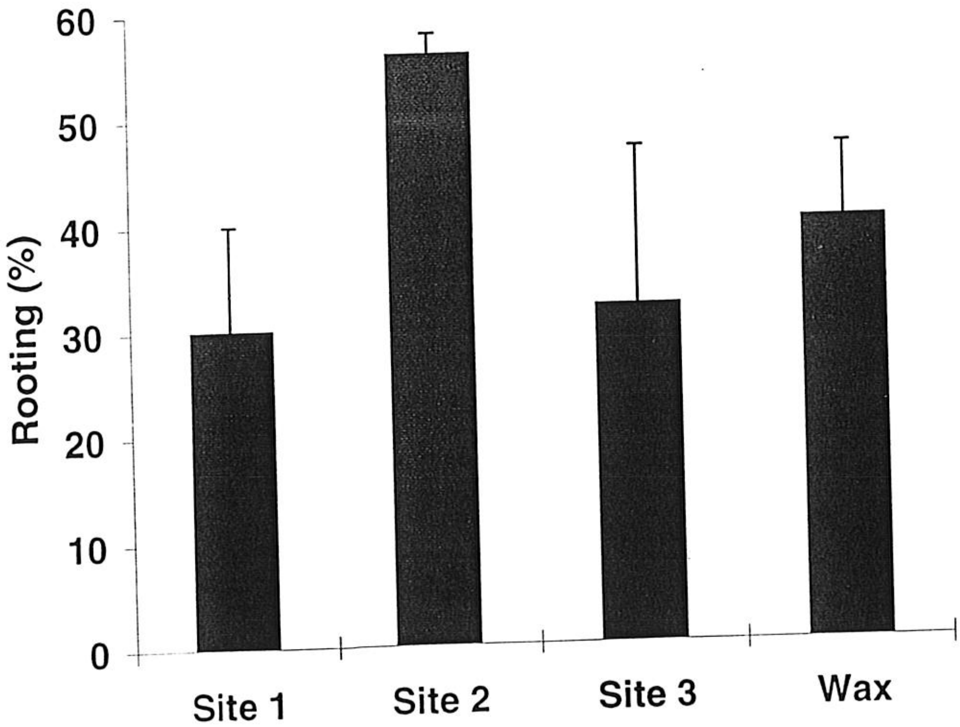


Figure 3. Colour Plates

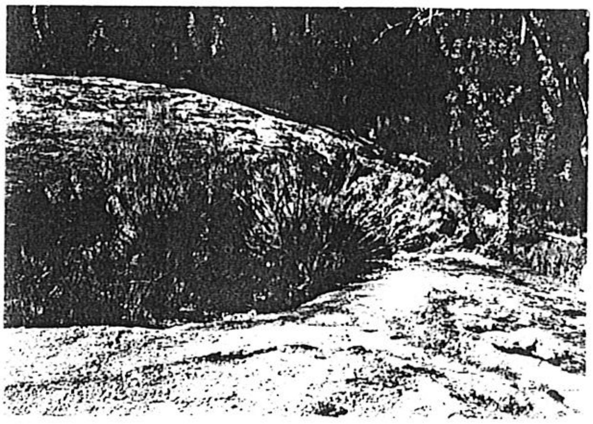
a. Resprouting *Agonis linearifolia* 8 months since cool burn, occurring in a fire accessible crack close to forest.

b. Large flat area of granite outcrop, accessible by fire, that is dominated by *Agonis linearifolia.*

c. Sub-population of *Astartea* sp. that was not scorched or burnt by a recent fire. This pocket of soil is elevated from the surrounding forest buffering the sub-population from both flames and heat of the fire.

d. This mature sub-population is approximately 4 m tall and occurs at the very top of the outcrop. The distance and isolation from the surrounding forest means it would only be scorched in the advent of a hot fire.

Figure 3 :Distrubtion on Astartea .sp in Relation to Fire Accessability of Outcrops



a.

b.

c.

d.

Figure 4 :Sub Population Showing Even Aged Maturity

a.

b.

Figure 5 :Skeletal Remnants of Similar Size Representing Previous Generation

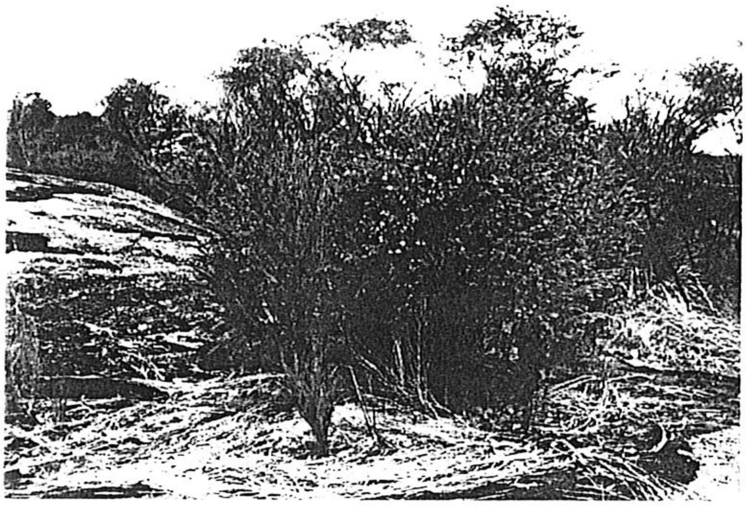
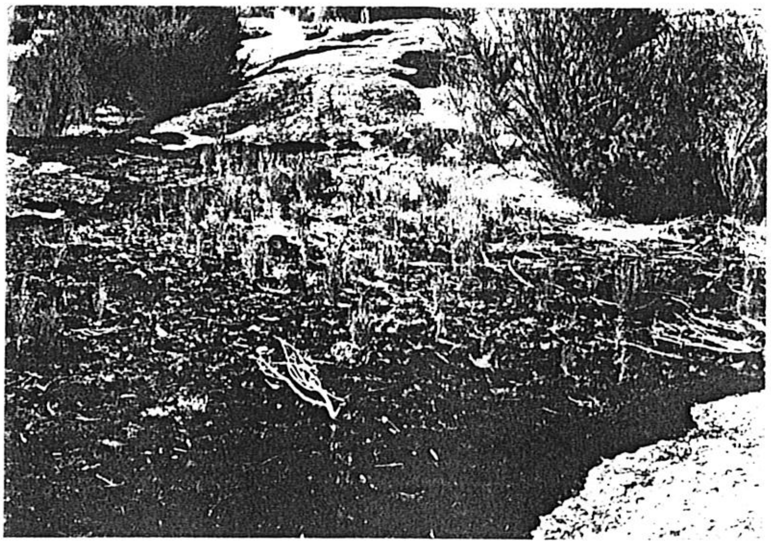


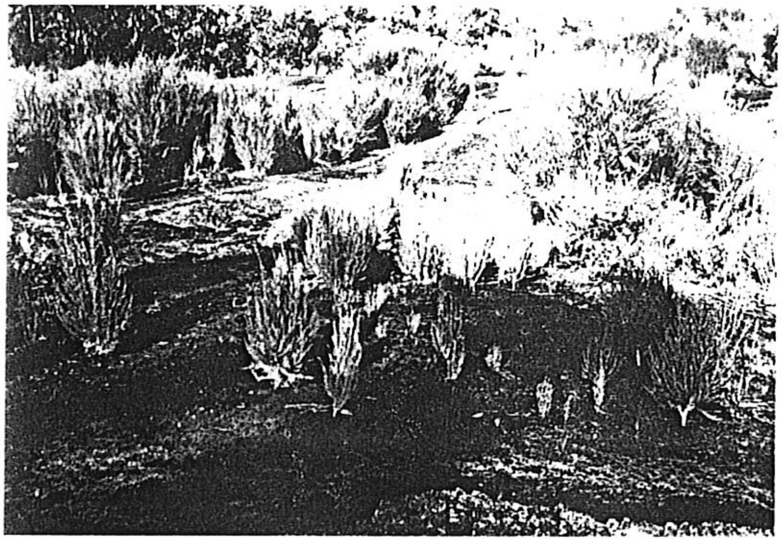
Figure 6 :Two Distinct Growth Forms Existing in the Same Population

a. b.

Figure 8 :Growth of a Juvenile Sub Population Over Eight Months



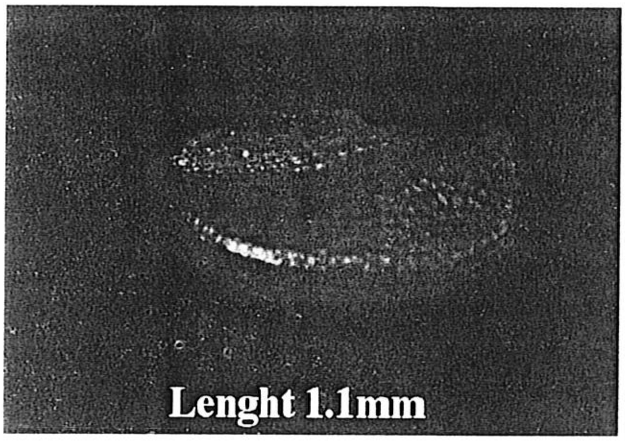
1a. February



1b. June

1c. December

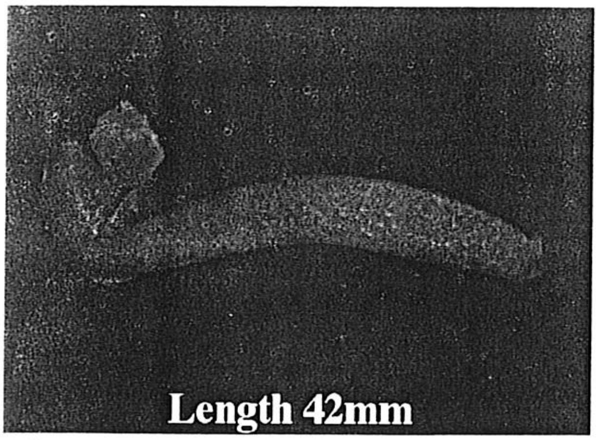
Figure 9 Seed Morphology and Germination type



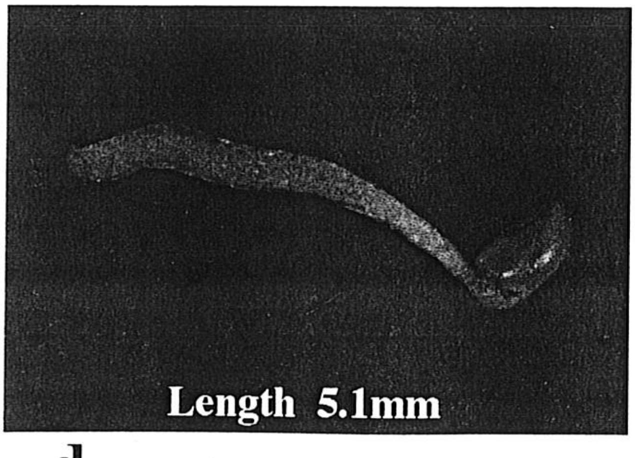
a.

b.

hypocotle length? see p. 36

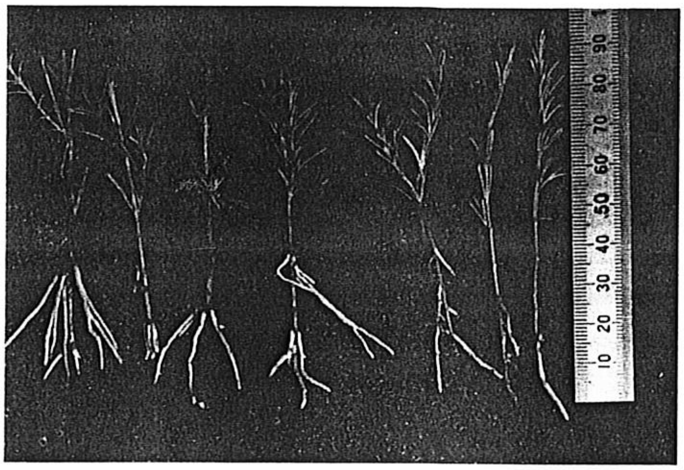


c.



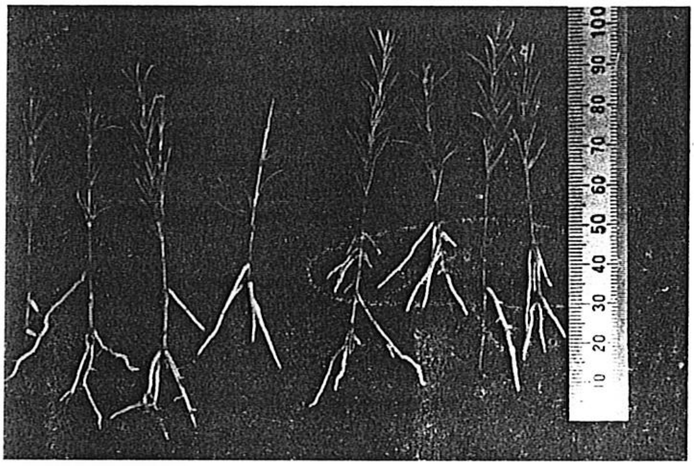
d.

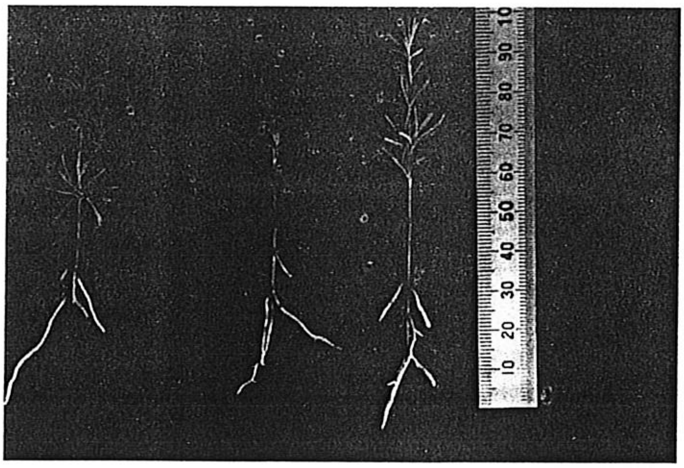
Figure 16 :Four Month Old Vegetative Cuttings Taken in February from Three Seperate Sites



Site 1 6-6-97

Site 2 6-6-97





Site 3 6-6-97

Site 3 Senescent 6-6-97

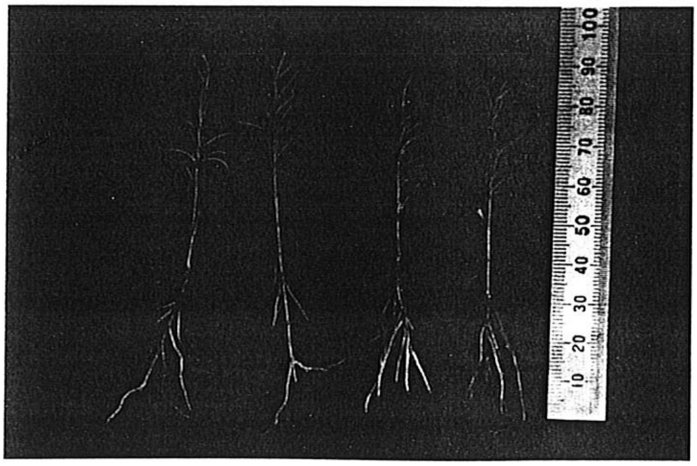
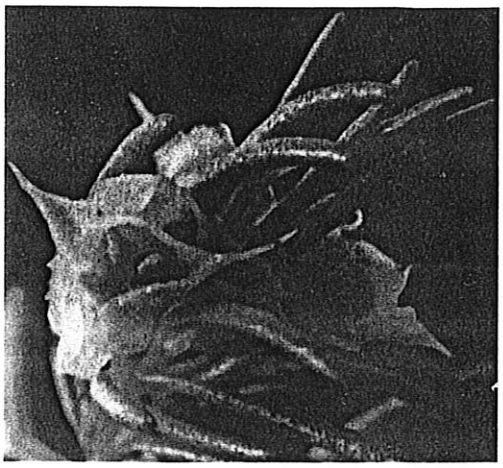
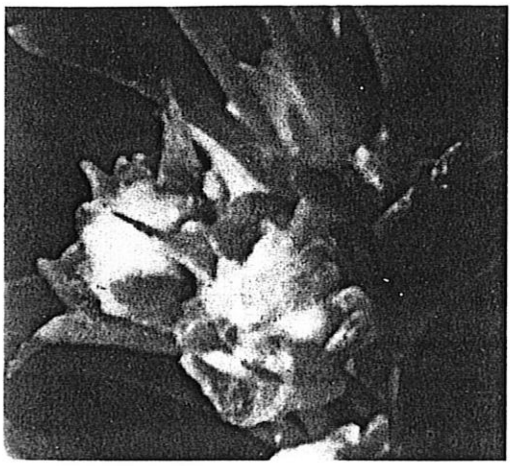


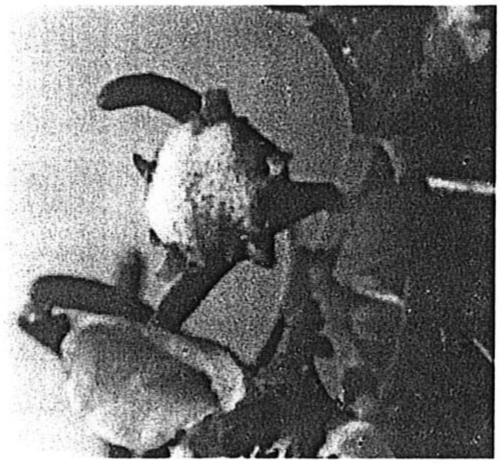
Figure: 17 Hedonic Scale of Flower Development



a. Sunken

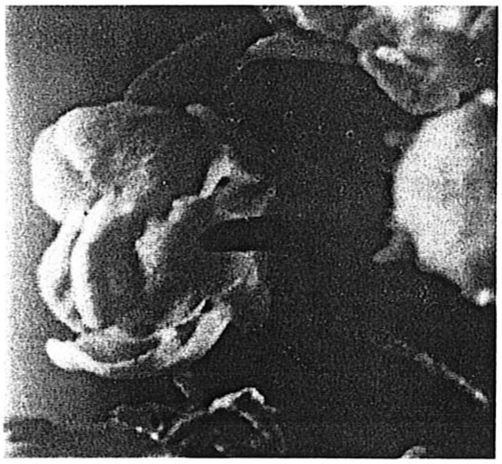


b. Star

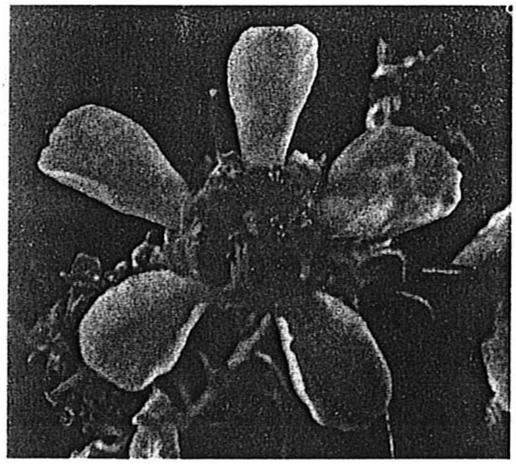


c. Domed

d. Ballooned



e. Open



f. Open

g. Senescent

h. No petals

Discussion

This species exists solely on these granite outcrops. Reference needs to be made to the environmental variables that exist in the surrounding forest in comparison with variables experienced on the granite outcrop. Identification and examination of significant environmental differences, such as fire intensity and frequency, soil characteristics, light, temperature and water availability will help to draw conclusions about the ecology of this *Astartea* species.

Fire plays an integral role in regulating the abundance or rarity of species in the south west and is the most selective agent in the evolution of southwest flora (Bell et al., 1993). Fire appears to be the most significant variable controlling the incidence of this species across the landscape. *Astartea* sp. was only found on granite outcrops of a particular size, shape and profile. Known populations occur on outcrops between 0.75 and 10 hectares. There shape is highly varied but generally circular rather than elongate. Pockets of soil on narrow outcrops are closer to fire and more likely to suffer from heat scorch than circular outcrops. Outcrops with a flat profile are more likely to be burnt or scorched by fire than elevated outcrops (Fig. 3b). The occurrence of *Astartea* sp. is therefore dependent on a combination of profile, shape and size. Populations of *Astartea* sp. occur in pockets on the rock that are not regularly subject to heat scorch or fire from cool burns. During hot burns was to occur it is expected that the vegetation on the entire rock would either burn or be killed by superheated air. *Astartea* sp. was only found on granite outcrops which contained a topography which included depressions, pockets or cracks, where *Astartea* sp. could be protected from fire. Aborigines practised frequent cool burns for 40 000 in the south west. Arrival of Europeans to the area saw fire regimes, which tend to be less frequent, larger and more severe (Christensen, 1992). CALM has now adopted regular spring and autumn burning practices, which more closely resemble aboriginal fire history. A change from aboriginal fire frequency will alter the selection pressure on vegetation favouring the resprouter species (Bell et al., 1993).

Field observations, supported by laboratory studies, on seed germination showed this species is an obligate seeder and is likely to have adapted to the fire regime practised by the aborigines. This *Astartea* sp. has a seed dispersal syndrome typical an obligate seeders. It was not observed to have a lignotuber or to resprout after fire. Observations suggest it reproduces entirely from seed. *Astartea* sp. produces and annually releases from capsules copious quantities of small seed (Fig. 9 a) like numerous other Myrtaceae such as *Baekea* and *Kunzea* (Beardsell *et al*, 1993). Release of such large seed numbers could probably satiate seed harvesting predators and provide a large seed bank giving a maximum chance for *Astartea* sp. to dominate in these soil pockets. High sub-population plant densities occurred even with no apparent fire event. This suggests that even low germination rates of non smoked seed could result in high plant density from the seed bank. After an environmental cue such as fire the *Astartea* sp. seedlings would be able to compete for all available germination sites.

Releasing seed annually also becomes critical in the event of dry summers. Across all of the sites visited there were pockets of plants that had died apparently from lack of water over summer (Fig. 5). These groups of dead plants were most prevalent on the shallow soil pockets with small catchment size. These shallow pockets of soils may hold insufficient water for numerous plants to survive summer. *Astartea* sp. is an annual seeding species and populations could quickly re-establish from the soil seed bank in the same site during the following winter. Without smoke treatment germination rates would be significantly lower (Fig. 10) however high seed numbers in the soil would result in numerous plants (Fig. 8a). Seeders and resprouters have different root morphologies which would tend to suggest that their ability to survive on the small, shallow pockets of soil on these outcrops would differ and therefore affect their relative distribution in these environments. Seeder species tend to have shallow fibrous roots compared to woody, deep roots of resprouters (Bell et al., 1993). *Agonis linearifolia* is a resprouter and was observed to be one of the most dominant species at the base and fire accessible areas of the outcrop. In the less accessible, isolated pockets seeder species such as *Chamelaucium forrestii* and Astartea sp. were prevalent.

Not all outcrops from the southern forest region that had suitable size and shape characteristics supported the *Astartea* sp. This may be a result of microclimatic differences in particular temperature and rainfall patterns. All the known populations occurred close to the coast and within the 1000 mm isohyet (Fig. 1). Therefore it is believed that this *Astartea* sp. requires 1000 mm rainfall or higher to survive on these outcrops. During the summer months granite outcrops are subject to high ambient and soil temperatures, without rainfall this results in low soil moisture content in the shallow soils. The significance of this distribution pattern is that the proximity to the coast provides cooler summer air temperatures, higher relative humidity and the >1000 mm rainfall results in longer period of rainfall during the year .

Astartea sp. was not found in the surrounding forest and may be unable to successfully compete with the forest understory. This may also be linked to its fire syndrome. Many other species of obligate seeders are able to successfully compete in the understory but this species is not able to do so. The small seed size of the *Astartea* sp. may result in slow initial seedling growth rate. The time to germinate and establish may be too slow to compete with other understorey species.

Soil characteristics may also affect distribution of *Astartea sp.* *Astartea sp.* grow in soil of low pH compared to the surrounding forest. Seedlings potted from the cutting trial grow well at soil pH similar to that found in the forest surrounding the granite outcrops. This indicates that pH alone is not limiting. It is more likely that seedlings of the *Astartea sp.* are unable to establish as quick as the resprouter species that dominate the surrounding vegetation.

The average pH of the soil on these outcrops was 4.7 (Table 2). At pH values this low most native species would be unable to obtain sufficient soil nutrients. This *Astartea* sp. has adapted to cope with this low soil pH.

Another physiological adaptation is the ability of this plant to survive and grow in soil that is waterlogged for up to six months of the year. Waterlogged soils create an anaerobic environment, which inhibits respiration of root tissue. Continual anaerobic conditions result in the death of plants. The frequent influx of rain water into these soil pockets would replenish oxygen levels in the soil water and rainfall throughout the year is more common at greater than 1000 mm of annual rainfall. This is considered a high rainfall zone. During the period of high soil water content, soil and ambient temperatures would be at their lowest, resulting in reduced plant respiration and therefore reduced oxygen requirement.

The soil pockets that exists on these outcrops may be unsuitable for the growth of most of the perennial plant species that occur in the area adjacent to these granite outcrops. *Astartea* sp. appears to have suitable adaptations that allow it to not only grow but to flourish in this environment. This includes the ability to cope with prolonged water stress combined with high soil and ambient temperatures. In summer, *Astartea* sp. quickly drop leaves, beginning with the older leaves at the base of the plant. This would reduce transpiration rate, while allowing shoot tips to remain active. Beyond the scope of this study is the oil content of leaves and their affect on drought tolerance. It is believed that the higher oil content of the leaves in summer is a mechanism of drought tolerance. The storing of oils in leaves rather than starches allows plants to store energy with less requirement for internal water. The commercial potential of these oils is unknown. The fitness of a given sub-population to survive to maturity depends in the volume of soil, catchment size, plant density and the amount of summer rainfall.

Soil nutrient levels differ between granite outcrops and the surrounding forest. The nutrients in soil on granite outcrops may come from several sources. Granite is thought to be the parent material of many soils of the southwest of Western Australia. It is rich in minerals such as potassium, phosphorous and other microelements (Mc Arthur, 1991) In addition the high organic matter content found in these soils (Table 2) would result in a high exchange capacity. Nutrients are therefore not easily leached out of the soil. This is particularly important in such a high rainfall area and because significant quantities of water pass through these soil pockets as run-off. Nitrogen levels in the analysis were comparable to karri and jarrah soils (Mc Arthur, 1991). The majority of nitrogen in forest soils is fixed by legumes and nitrogen fixing soil bacteria. On granite outcrops supporting *Astartea* sp. some soil pockets contained *Eutaxia obovata,* a species which fixes nitrogen, but most did not. No other nitrogen fixing species were observed in significant numbers on outcrops. The continual washing of mosses and lichens into these soil pockets is also a likely source of soil nitrogen. Ash and dust that is washed into these soil pockets is also a likely source of other nutrients. Much of the soil nutrients may also be locked up in soil biota. Mycorrhiza are known to improve the efficiency of most native species in obtaining nutrients, particularly phosphorous, from nutrient poor soils (Abbot, 1994). These soil fungi essentially increase the surface area of the root in contact with the soil, therefore improving nutrient uptake and are believed to also help certain plants uptake water. Further research is required to examine the role of mycorrhiza in the ecology of granite outcrops. A mycorrhizal association with *Astartea* sp. may be an adaptation evolved to cope with the limited soil volume.

The growth rates obtained *in situ* were not carried out over an entire year therefore predictions of time to flowering and absolute growth rates are inaccurate. These figures do not represent total growth including branching and do not account for seasonal flushes in growth. Growth rate of a juvenile sub-population over 8 months indicates the rate at which *Astartea* sp. establishes in a soil pocket (Fig. 8).

Many stands of *Astartea* sp. were of a similar age. The occurrence of even-aged stands of *Astartea* sp. may extend further than synchrony of germination events (Fig. 8). At all of the sites visited seedlings could not be found in mature sub populations, even if conditions were suitable. This indicated possible allelopathy, either as a germination or growth inhibitor. In these habitats such an adaptation may prove valuable for the reduction of competition for resources in the limited soil pocket. This is expected to give a sub-population a better chance of completing a full life cycle. It could be suggested that sub-populations exhibit synchrony as a result of seed germination following a fire event. However, the frequency of fire across the outcrops studied did not match the differences in growth of sub populations (Fig. 8). In one case the development of a juvenile sub-population occurred however, the last fire near this outcrop was 12 years before the presumed germination date. Bell *et al.* (1993) suggests that in the south west of Western Australia the first plants to establish, utilise all the available water and nutrients. In this initial floristic model plants are not introduced over time as in a succession system. The very limited soil resources available on granite outcrops are likely to be quickly utilised by the *Astartea* sp. resulting in both even aged stands and often monotypic sub-populations.

Seedling morphology was of the epigeal type. After emergence of the shoot the hypocotyl elongates rapidly before the development of the root and the cotyledons (Fig. 9). Epigeal germination of *Astartea* sp. may be a further adaptation to this granite environment. The thick covering of moss on the soil surface would otherwise prohibit emergence of the seedling. Rapid elongation of the hypocotyl allows the emerging seedling to penetrate through the moss therefore exposing the cotyledons to light. Seeds with hypogeal germination may be restricted from emerging from the moss covering.

Seeds of this *Astartea* sp. have a dormancy mechanism. Germination proportion was far greater following smoke treatment compared with non smoked seeds (Fig. 10). Untreated seeds reached a maximum germination rate of 12% at 15^{0}C while smoke treated seed reached 77%. The need for seed dormancy could be considered imperative for the survival of this species in an environment that experiences infrequent wetting over summer when dry and hot conditions predominate and cool wet conditions over winter. The germination of the *Astartea* sp. is sensitive to both smoke and temperature.

Germination rate of both smoked and non smoked seed was effected by temperature (Fig. 11). The highest germination rates were achieved at 5^{0} C and 15^{0}C with a decline in germination at temperatures higher than 15^{0}C. This germination regime matches the winter temperature pattern (Christensen, 1992). It is expected that germination is timed for winter when water is not limiting therefore allowing a maximum chance of seedling survival. This winter germination regime occurs in many Myrtaceae species and encourages seedlings to become established before summer (Bell *et al*, 1993). This type of germination is particularly pertinent for survival on these granite habitats. The availability of soil water would rapidly decline as temperatures increasing over a constant soil temperature of 15^{0}C, this represents the onset of the dry summer months. At temperatures below 15^{0}C in winter the soil pockets are prone to water saturation and may be considered unsuitable for growth of the emerging seedling as a result of anaerobic conditions.

Due to the scattered nature of vegetation and the distance from the surrounding forest vegetation, many of the outcrops did not appear to support fire. The nature of movement of hot air up slopes suggests that super-heated air from the surrounding fire would cause the death of outcrop vegetation by scorching it. It is possible that during fires in the surrounding forest the soil temperature on the granite outcrop is not substantially raised. Heat or eluates from charcoal would be an unlikely mechanism to break dormancy for plants existing in this environment. Diffusion of smoke into the soil and the washing of soluble smoke compounds into these soil pockets however, is highly likely. Dixon and Roche (1995) suggest that smoke may play a role in diffusing to layers of soil out of the range of stimulation by heat. The same principle is likely to occur on granite outcrops not frequented by fire.

Germination was stimulated by smoke over a wide concentration range (0.3 to 30%; Fig. 10). A 10 % dilution is recommended for the successful germination of most W.A seeds (Kings Park Bot Gardens) however substantial (73 %) germination occurred even at a very low concentration (0.3 %). It may be that the soil pockets are only exposed to very diffuse smoke and that the seed has adapted to low smoke concentration as a cue for germination.

The inhibitory effect of smoke at high concentrations may be an adaptation of *Astartea* sp. (Fig. 10). If fires occur during times of the year where soil moisture is limiting the chances of high concentrations of smoke compounds in soil solution would be greater. Inhibition of smoke at high concentrations (100%, Fig. 10) may act as a delay mechanism for better rainfall conditions. After sufficient rain the smoke compounds would be diluted and the chance of seedling survival increased. If most of the seed bank was to germinate after the first rain event following fire there may not be sufficient soil moisture to support seedling growth. The seed appears to have a dormancy mechanism that inhibits germination at temperatures higher than 20^{0}C (Fig. 11). Natural fire events often occur during the hotter times of the year and would otherwise provide the cue for germination of the seed bank. If sufficient rains did not follow the majority of the seed bank would be lost and chances of species survival would be reduced. The apparent inhibition of seed germination at summer temperatures would minimise such an event.

The effect of light on the germination ecology of this *Astartea* sp. was not examined. However, owing to the small size of the seed and the high light environment of this habitat, similarities can be made with other native species where light plays an integral role in germination ecology (Plummer and Bell, 1994). Light is not limiting in these environments due to their elevation above the surrounding forest. The proportion of red to far red light that reaches the soil pockets would be higher than that found on the surrounding forest floor. The light intensity is also expected to be higher. Numerous native seeds have a germination response to different light quality and intensity (Plummer, 1994). Much of the *Astartea* sp. seed is dispersed onto the surface of the granite, soil or moss. The chance of survival of seed would be poor unless it was contained within the soil or covered with moss. The moss covering is dense and underlying seed would be exposed to far red light or maintained in the dark. Light may contribute to the apparent even aged growth stands which were observed across all populations. A fire event or a very dry summer which induces senescence would remove vegetation (Fig. 5). With the removal of the plant canopy, the intensity of light and the quantity of red light at the soil level would increase.

Seed propagation of the *Astartea* sp. may prove an inexpensive method of mass propagation. The dormancy mechanism imposed by the seed was successfully broken with smoke water. Optimal seed germination (77%) was achieved by treating seed with a 30% dilution of smoke water (Kings Park and Botanic Gardens) and maintaining germination temperature at 15^{0}C. The high germination percentage obtained, after dormancy was broken, indicated a high rate of seed viability. The rate of seedling growth from seed and genetic variability would be important issues in horticulture and should be examined.

Vegetative propagation can be used for species that do not produce viable seed or where dormancy can not be broken. It is also an effective method of clonal reproduction for the selection of specific plant characteristics such as flower colour. This form of propagation is more labour intensive than using seed, however, it may prove necessary if superior selections of *Astartea* sp. plants are made. Methods that increase the rooting percentage significantly reduced the cost of this method of propagation.

Astartea sp. could be propagated from cuttings and it had rooting percentages comparable with commercially grown *Astartea fascicularis* where success rates are up to 83% (Dawson and King, 1994). Tip cuttings taken in January had a 95% rooting success rate (Fig. 12). Tip cuttings taken from 1 to 2-year-old parent material in mid-January, treated with auxin and struck in a peat:perlite (1:1) media, give the best results. Cuttings should be struck in individual tubes rather than all in the one seedling tray to avoid high mortality rates after transplanting. This avoids mechanical damage to the roots and the chance of fungal infection.

Auxin (IBA) application improved the rooting percentage (Fig. 14). Auxins are widely recognised as root stimulants and have been used to promote rooting in other members of the Myrtaceae family (Dawson and King, 1994). The application of 8 gL^{-1} to cuttings taken in February resulted in 80% of tip cuttings forming roots compared with 50% of tip cuttings treated with 3 gL^{-1}. Rooting is usually improved with cuttings taken at an optimal time of the year. Rootability of cuttings was greater in January and June than February (Fig. 12). Hormones such as abscisic acid may be in higher concentration in plants with higher water stress (Hartmann 1990).

The maturity of stem tissue and the position taken from the plant influenced rooting. Basal cuttings rooted less than tip cuttings overall (Fig 12&13). This may be due to the presence of endogenous phenols in the cutting. Higher phenol concentrations in basal cuttings of *Chamelaucium uncinatum* inhibits rootability (Curir et al., 1993). Flavonoids improve rooting and are in higher concentration in the C. *uncinatum* tip cuttings . Lignification of stem tissue increases from the tip and may act as a physical barrier to production of roots from the base of cuttings.

Cuttings taken in mid-January and June had similar strike rates but both were significantly higher than material collected in February (Fig. 12). The most significant difference in the plant physiology between February and January, June is the state of plant dormancy resulting from water stress. Plants in January did not express signs of water stress to the same degree as those in February, and in June following recent rainfall plants were actively growing. Water stress was expressed as leaf drop and reddening of leaves. A similar response to water stress occurs in Geralton wax, which reduces growth, sheds leaves, adjusts its stomata and modifies leaf angle (Akilan, 1994). Higher concentrations of endogenous growth inhibiting hormones such as abscisic acid, are expected water stressed in February cuttings, and this may result in inhibition of root initiation.

Rooting response does not appear to be governed by carbohydrate levels in stem tissue but this may account for the small difference in rooting percentage between January and June. While plants are not actively growing they maintain a higher concentration of carbohydrates in stem tissue. Cuttings use carbohydrates as an energy source for the production of roots. Cutting material from June would have less stored carbohydrates than January because these plants are actively growing .

Rooting percentage decreased with increasing age of the parent plant (Fig. 13). As parent plants age the relative growth rate decreases, and their requirement for water increases and the amount of lignification increases. Juvenile plants generally have a greater ability to produce roots (Hartmann, 1991).

The composition of media used to strike cuttings affected the rooting percentage (Table 4). Peat and perlite mixed in the ratio of 1:1 or 2:1 gave the best rooting average compared with pure peat and perlite or other combinations. Total percentages for this trial were not high due to cuttings being taken in February when rooting overall was reduced. The water holding capacity and porosity of a media affects rooting percentages of cuttings and should be suited to the type of propagating system used (Handreck, 1991). Perlite has a very low water holding capacity but a high porosity which is opposite to peat therefore a balance needs to be met to obtain optimal rooting. The media functions to provide support and moisture, while allowing penetration of water to the base of the cutting. Mixing the peat and perlite 1:1 and 2:1 resulted in a combination of water holding capacity and porosity that best suited the development of roots on *Astartea* sp. The incidence of root disease was higher in the misting room than when clear propagating hoods were used and cuttings hand watered. Open mixes are drain quickly making conditions unfavourable for disease. Relative humidity in the misting room is high and rooting media does not get the opportunity to dry out. Plants put under stress from inadequate watering are not as resistant to fungal attack. Hand watering and using hoods reduces soil saturation but may cause some water stress. Root disease problems may be overcome and strike rates improved using a fine mist or fogging system combined with higher porosity media so that the soil stays moist but does not become saturated, therefore reducing the conditions for root disease. The smaller particle size of the fogging system and the more frequent misting results in a higher degree of oxygen diffusion into the water therefore, cuttings are provided with better conditions for respiration. Hand watering gives large one off applications that drench the media allowing for little diffusion of oxygen into the soil water. High water content of propagating media promotes the germination of spores and the proliferation of fungal hyphae. The fungicides applied were of limited benefit possibly as a result of fungal resistance and it may have been useful to use a more diverse fungal rotation.

Significant differences existed between the rooting percentages from 3 separate sites. Differences in rooting percentage between sites has implications for selection trials where material is likely to be taken from any of the 8 known populations and vegetatively propagated. When observing the difference in the strike rate of cuttings taken through the year is should also be noted the time to reach maximum rooting percentages. This affects the cost of producing plants by vegetative means.

The floral display of this species makes it suitable as a floral filler or floral foliage filler. *In situ* flowering stems can be picked at lengths greater than 30 cm and this is likely to be improved in cultivation. The timing of flowering is between October and December and at this time of year there are few Myrtaceous species marketed as floral fillers (Karingal, 1994; Manning *et al,* 1996). Flowering this late in the year would enable the *Astartea* sp. to be sold to the Christmas market. The timing of flowering of this species occurs after the peak production of the floral fillers, *Chamelaucium* and *Thryptomene.* Initial studies of a single genotype and initial field observations show this species has a short vase life. Petal drop occurred 8 days after opening. It is not known if this species is ethylene sensitive however other species of the *Chamelaucium* alliance are. If this is the case it may respond to silverthiosulphate (STS) pulsing. Once absorbed STS blocks the biochemical pathway responsible for the synthesis of ethylene. The flowers of C. *uncinatum* are ethylene sensitive and petal drop is reduced when stems are pulsed with STS (Manning *et al,* 1996). A promising characteristic of this species is it's ability to continue to develop flower buds from an immature stage through to opening while in a vase. this response has been observed to a lesser extent in postharvest stems of C. *uncinatum* (Hall, pers comm). It may be possible to harvest stems prior to bud opening. This is a rare characteristic in Australian cut flowers and this requires more research. The foliage vase life was 18 days for apical stems and 9 days for basal stems. Osmotic regulation is expected to differ through the year with changes in ion content and continued water stress. This is likely to change the foliage vase life and requires further examination.

It is expected that genotypes could be selected that exhibit much improved vase life (Slater, 1996). The results of this post harvest trial are only given as a guide and for sound conclusions to be drawn as to postharvest issues further research needs to be carried out while this species is in full flower.

There are a few *Astartea* species that are currently grown as pot plants for landscape plantings. This *Astartea sp.* shows considerable potential for use as a medium sized pink or white flowering landscape shrub. When the environmental cues that initiate flowering are determined this species could have considerable potential as a flowering pot plant (Dawson and King, 1993). If adequate vase life can be obtained then a niche market could exist for the sale of this species to overseas markets as a floral filler. For the full potential of this species to be met, further research is required in the selection of plants that have improved floristic characteristics. If this species is to be used in the cut flower industry attention needs to be made into appropriate postharvest treatments but more importantly testing lines of plants for improved vase life. It may also prove possible to breed cut flower cultivars of *Astartea sp.* using interspecific hybridisation (Bicknell, 1995). This would be particularly important for extending the harvesting season of currently available myrtaceous species.

For a more accurate analysis of the flower development of postharvest stems flower tagging needed to be carried out for each of the floral stages (Fig. 17). From this type of analysis it would be possible to document the rate and degree of development of flowers on stems after harvest. This would indicate the stage of maturity that plants could be harvested and the expected life of the flowering stem.

Conclusion

The ecology of this *Astartea sp.* like much of the flora of the south west is governed by fire. The history of fire practices of this region have placed selection pressures on this *Astartea sp.* and the specific adaptations of this species ensure its growth and survival on these unique habitats. The *Astartea sp.* is an obligate seeder that does not occur on granite outcrops that are readily burnt by cool fires. Its adaptations to water stress, high pH, shallow soils give it a competitive advantage over resprouter species which occupy areas of the outcrop that are frequented by fire. Seeds have a dormancy mechanism that is essential for survival in this environment. Smoke, winter temperatures and rainfall are required to break seed imposed dormancy and germinate seed.

Vegetative propagation was possible and rooting percentages are suitable for commercial production obtained. Tip cuttings taken from 1 to 2-year-old parent material in mid-January or June, treated with auxin and struck in a peat:perlite (1:1) media gave the best results. High mortality rates occur after root disturbance, therefore cuttings should be struck in tubes to avoid transplanting. Placing cuttings in a fogging propagation system improved rooting percentage and reduced the incidence of root disease.

This Astartea showed considerable potential as a flowering pot plant and landscape plant. Its potential as a floral filler is heavily dependent on the selection of genotypes with longer vase life or the identification of appropriate postharvest treatments.

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SUMMARY OF CSBP SOIL ANALYSIS METHODS

PHOSPHORUS AND POTASSIUM

REF: Colwell, JD (1965) Chem & Ind 893-895.
Rayment, GE and Higginson, FR (1992). 'Australian Laboratory Handbook of Soil and Chemical Methods.' (Inkata Press, 1992) pg 64.

Available phosphorus and potassium are measured using the Colwell method:

Soils are tumbled with 0.5M sodium bicarbonate solution adjusted to pH 8.5 for 16 hours at 25°C employing a soil:solution ratio of 1:100.

The acidified extract is treated with ammonium molybdate/antimony trichloride reagent and the concentration of phosphate is measured colorimetrically at 880nm.

The concentration of potassium is determined using a flame atomic absorption spectrophotometer at 766.5nm.

AMMONIUM AND NITRATE

The ammonium and nitrate nitrogen are measured simultaneously using a Lachat Flow Injection Analyser. Soils are tumbled with 1M potassium chloride for 1 hour at 25°C employing a soil:solution ratio of 1:5.

The concentration of ammonium nitrogen is measured colorimetrically at 420nm using the indo-phenol blue reaction. REF: Searle, PL (1984) Analyst 109, 549-568.

The nitrate is reduced to nitrite through a copperized-cadmium column and the nitrite measured colorimetrically at 520nm.

pH WATER, CONDUCTIVITY AND pH CALCIUM CHLORIDE

REF: Rayment, GE and Higginson, FR (1992) "Australian Laboratory Handbook of Soil and Water Chemical Methods" pages 15-23.

Soils are stirred in deionised water for 1 hour at 25°C employing a soil:solution ratio of 1:5 The pHw of the extract is measured using a combination pH electrode calibrated against 0.01M KCl.

After pHw and E.C have been measured, calcium chloride solution is added to produce a concentraion of 0.01M $CaCl_2$ and pHc in determined using a combination pH electrode.

ORGANIC CARBON

REF: Walkley, A and Black, IA (1934) Soil Sc 37, 29-38.

Concentrated sulphuric acid is added to soil wetted with dichromate solution. The heat of dilution is used to induce oxidation of soil organic matter. The amount of chromic ions produced is proportional to the organic carbon oxidised and is measured colorimetrically at 600nm.

REACTIVE IRON

Soils are tumbled with Tamm's reagent (oxalic acid/ammonium oxalate) for 1 hour employing a soil:solution ratio of 1:33. The concentration of iron is determined using a flame atomic absorption spectrophotometer at 248.3nm.

EXTRACTABLE SULPHUR

REF: Blair, GJ, Chinoim, N, Lefroy, RDB, Anderson, GC and Crocker, GJ (1991) Aust J Soil Res 29, 619-626.

Soils are extracted at 40^{0}C for 3 hours with 0.25M potassium chloride and the sulphate sulphur is measured by ICP.