Bio-architectural technology and the Dreamtime knowledge of Spinifex Grass[1]

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Abstract

This paper is premised on several Australian Aboriginal myths (or sacred histories) from the Georgina River Basin region of Central Australia that concern the *Triodia* grasses known locally as spinifex (or *aywerte*). These sacred histories provide an epistemological foundation to the regional intellectual property over traditional spinifex technologies utilized for architectural, material and medicinal functions. Aboriginal uses of spinifex were once widespread but have declined in the latter 20th Century, and ethno-scientific knowledge has severely diminished. The dominant uses of spinifex in Aboriginal culture were as waterproof roof-thatching material and as a gum for adhesive functions. The paper explores the contemporary re-vitalization of this knowledge in collaborative research partnership between a group of traditional tribal owners (the Indjalandji, Wakaya and Bularnu peoples) and a team of scientific researchers from the University of Queensland lead by the author.

Keywords: architectural technology, Australian Aborigines, fibre architecture, spinifex grass, bio-materials, bio-composites.

1. Introduction

The author is the leader of multidisciplinary research project funded under the Australian Research Council (ARC) Discovery Projects scheme which is evaluating traditional Aboriginal knowledge and uses of spinifex grass. Spinifex is a collective term for 69 species in the genus *Triodia* which are widespread throughout semi-arid Australia. The project builds upon the ancient Aboriginal knowledge of spinifex as well as upon biomimetic theory, drawing from nature to find new technical solutions. This paper provides a preliminary report on the project team's findings with particular emphasis on the application of the ethno-architectural knowledge to the broader problem framework.

The ancient Aboriginal knowledge of spinifex (or *aywerte*) is embedded in myths or sacred histories which in the context of our study region are from the upper Georgina River Basin of Central Australia. (See Figure 1.) The paper explores the contemporary re-vitalization of this knowledge in collaborative research partnership between a group of traditional tribal owners, (the Indjalandji, Wakaya, Bularnu and Alyawarr peoples) and a team of scientific researchers from the University of Queensland.

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The operational venue for in-situ project experiments is the Dugalunji Camp of the Indjalandji group, near the town of Camooweal, an enterprise and training base with a population of up to 80 people. Planning and architectural design in the camp occurs according to Aboriginal directives and principles, and within a grounded understanding of the cultural landscape in which the ancient sacred sites with their sacred histories (myths) are embedded.

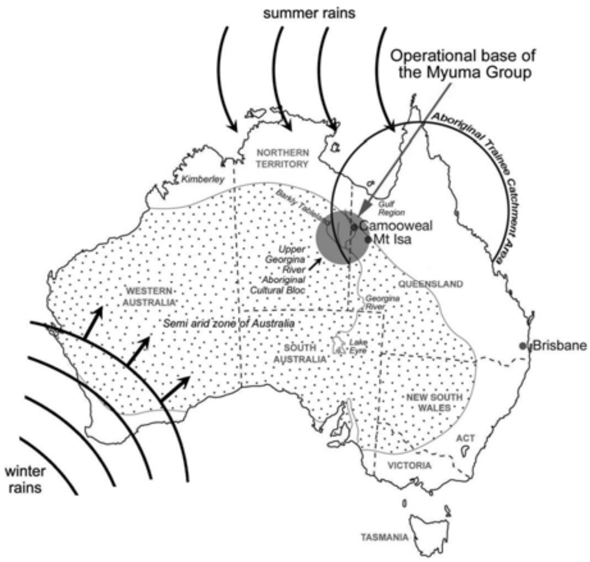

Figure 1. Map showing the project location on the edge of the semi-arid zone.

Current national economic use of spinifex is marginal, limited to a drought stand-by pastoral fodder. Our project explores uses and properties of spinifex as a future material for a sustainable building industry to replace current resource-intensive materials. Both fibres and resin have potential uses in building technology as either separate or combined (composite) products. *Triodia*-derived fibres and resin are being explored for potential uses in the building industry such as insulation batts, biodegradable plastics and polymer products. The research (in its fifth year) is exploring both low-tech building construction techniques that draw on traditional practice and have potential for local sustainable contemporary applications, as well as high-tech, laboratory-manufactured material products that may be of ultimate use in biodegradable architecture and artifacts.

An ecological aspect of the research involves understanding optimal plant propagation so as to develop sustainable harvesting methods. Thus, if commercialized material products can be developed, a cottage industry may be implemented to provide increased economic viability for remote-area Aboriginal camps and outstations in remote locations across the sparsely populated interior of the continent. Decentralized bio-refining plants are a further possibility.

The main geographic focus of our study is in an area with little previous ethnographic recording of spinifex usage, that of the upper Georgina River basin region bridging between the central-east Northern Territory and the central-west Queensland. The area was chosen because of the range of spinifex species growing across diverse habitats, our well-established relationships with local Aboriginal communities (particularly the Indjalandji group at Camooweal), recent, positive, economic developments in these communities, and current plans for establishing a remote Arid Zone Field Station in the region for the University of

Queensland. The temperature profile for the Camooweal area is consistent with a hot desert climate with the main rainfall events in summer. The interior location of the site incurs dual climatic influences with summer monsoonal conditions from the Gulf of Carpentaria to the north and winter rain fronts from southern Australia coming east across the interior deserts. This climate imposes periods of under-heating and over-heating in a regime of low humidity for most of the year, characteristic of desert climates. Building strategies such as thermal mass and evaporative cooling can modify climatic performance to reduce building energy costs.

2. The Sacred Histories of the Georgina River basin

Throughout the semi-arid parts of Australia, *Triodia* grasslands represent Aboriginal cultural landscapes of significance, incorporating selected areas which were harvested for a range of economic and material purposes. The significance of *Triodia* as a resource is reflected in foundational religious (or cosmogenic) beliefs concerning the Dreaming, sacred sites and the reproduction of species. Aboriginal 'increase' ceremonies are believed to have been passed down for many generations from Ancestral Beings of the Dreamtime. The function of such ceremonies is to catalyse the healthy increase or reproduction of various animal, plant or meteorological phenomenon which constitute totems in the Indigenous religious belief system, and by consequence, the total food supply. Through their ritual actions, the participants believe they connect with the *Altyerre* or Dreamtime dimension, and renew a spiritual energy linking this dimension of the Ancestors with the world of mortal humans. Aspects of the travel of the Ancestral Beings are retold or re-enacted in the ceremonies through song, ritual, and artworks with musical accompaniment.

Increase ceremonies were once performed on the upper Georgina region for the phenomena of Spinifex Grass, Spinifex Resin, Rain and Fire, which were interspersed with the annual seasonal cycles of (a) the growth of spinifex grass, (b) the production of resin on the grass in the dry season (the harvest time), (c) the burning of spinifex by fire, and (d) the re-growth after rain. Another traditional Aboriginal practice was the mosaic burning of spinifex grasslands to encourage the reproduction of diverse flora and fauna resources. Use of spinifex resin as a medicine was once taught at a traditional Doctor's School near the James River (a tributary of the Georgina). Two Spinifex sacred sites are located on the upper Georgina basin with their sacred histories involving resin. These sacred histories of Spinifex Dreaming connect or relate to the Red Kangaroo, Wild Bee, Freshwater Bream, and Black-Headed Python totems joining distant groups in the wider region. These sacred histories provide an epistemological foundation to the regional intellectual property over traditional spinifex technologies utilized for architectural, material and medicinal functions.

3. The Colonial and Post-colonial History of the Georgina River

In the mid-19 century, the Indjalandji people occupied the upper Georgina River Basin and surrounding grass tableland (now the Barkly Tableland). A young man named Idaya, a forebear of the contemporary Indjalandji group, experienced the first impacts of colonisation in December 1861, when the British explorer William Landsborough encountered and renamed three sacred Indjalandji waterholes (Rain and Rainbow Serpent Dreamings) on the

Georgina River as Lakes Mary, Francis and Canellan. His favourable report on the surrounding grasslands triggered several waves of pastoral occupation by colonists during 1864–84. The township of Camooweal was established beside Lake Francis in 1884 and was to flourish as a border customs post, a pastoral industry service town and a droving stop for the 'cattle barons' bringing cattle from the Barkly Tableland and the Kimberley to the eastern coastal markets. Decimation of the Georgina Aboriginal groups occurred during the late nineteenth century due to frontier violence and multiple diseases. Partly in response to the widespread demographic collapse, the Queensland Government introduced the *Aboriginals Protection and Restriction of the Sale of Opium Act 1897*, which regulated, but also forced, Aboriginal people to labour in the pastoral industry. Despite these adversities, many customs were transmitted in the pastoral camps as Idaya's descendants worked under 'the Act' and intermarried with spouses from other tribal groups. As a result, a sense of a Georgina River Aboriginal culture and community survived.

In 1998, the Indjalandji descendants submitted a Native Title application under the Australian Government's *Native Title Act 1993* over the upper Georgina River around the gentrifying township of Camooweal. The river and its lakes form a complex Aboriginal landscape of sacred and secular sites with dominant Dreamings being Rainbow Serpent, Rain, Picaninnies and Blue Tongue Lizard. Knowledge of such has been maintained by the group through the difficult frontier era of disease, violence and discrimination all of which was key evidence in the Native Title Claim. In 1999, Queensland Main Roads Department commenced the development of a new Georgina River Bridge. The Indjalandji, using the cultural capital of their Native Title claimant status, managed to negotiate various project outcomes and benefits from Queensland Main Roads, including employment and training for themselves and other Aboriginal members of the wider community. In addition, a construction camp (the '*Dugalunji* Camp') was left in the hands of the Indjalandji group after the completion of the bridge so as to assist participation in the subsequent highway upgrades. By 2002, the Indjalandji had established the Myuma Group of corporations to further the well-being, cultural maintenance and quality of lifestyle of the Aboriginal people of their region. (Memmott 2010.)

4. The Botany and Ecology of Spinifex Grass

'Spinifex' (also commonly known as 'porcupine grass') is the generic term used to describe approximately 69 species of grass (Family *Poaceae*) within the genus *Triodia*. *Triodia* is widespread throughout semi-arid Australia, and adapted to high temperatures, low and erratic rainfall and soils of an oligotrophic nature (lacking in plant nutrients). Spinifex grasses are prickly evergreen xeromorphic plants, endemic to Australia and covering much of the continental landmass with a very conservative estimate of 27% (possibly as high as 40%) Spinifex grasses produce highly resilient leaves and grow as hummocks, clumps of prickly leaves and stems, and often develop into rings providing shelter for other plants as well as animals. Large areas of spinifex biomass are burnt by bushfires each year, releasing CO_2 and contributing up to 4% of Australia's annual carbon emissions. Current economic use of spinifex is limited to secondary seasonal pastoral fodder. (Memmott et al 2009.)

Spinifex is an aggressive arid-zone grass which quickly colonizes desert areas that have been severely burnt by fire. Once established, it perpetuates fire regimes due to its high flammability and thereby maintains its dominance. Individual hummocks can live for more than 20 or 30 years. However, if spinifex does not burn regularly, other fire sensitive shrubs can take over. (Latz 2007.)

Under normal arid conditions spinifex leaves are folded into a tight cylinder to form a needle-like leaf with a pointed end. Only after substantial rains do spinifex leaves unfurl into flat leaves (to look like other bladed grasses). Pronounced differences in leaf anatomy generate a division into 42 'hard' species with stronger fibres, and 27 'soft' species with weaker fibres but having a resin yielding capacity. Hard species appear to grow on drier terrain than soft ones, and are characterised by tough, stiff leaves that are painfully prickly. Aboriginal consultants on our project describe hard spinifex as the 'cheeky' type which has to be removed from its roots with a stick (i.e. at arms length) although it is said to be easier to handle when green, after rain. Hard spinifex species (e.g. *Triodia longiceps*) appear to have double the photosynthetic capacity of soft species with the anatomical apparatus for photosynthesis, *stomata* and photosynthetic tissue, located on both the outer and inner surfaces of the curved or folded leaves, as well as larger bundles of fibres for rigidity. By contrast, soft species only have this apparatus on the protected inner surface of the leaves and less fires, but they display a most unique attribute of generating a sticky resin from special cells that exudes onto the outer surface of the grass and whose function is not well understood scientifically. (Burbidge 1946, Gamage et al 2012.) (See Figure 2).

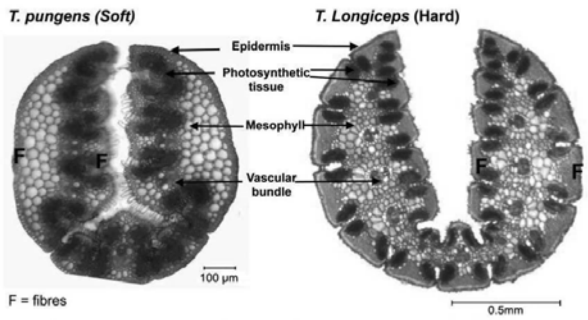

Figure 2. Leaf cross-sections of Triodia pungens and longiceps showing anatomical difference of soft and hard species. (Hard spinifex has more fibres, photosynthetic tissues & stomata on both surfaces, but soft spinifex exudes resin.)

The resin is primarily a mixture of volatile and nonvolatile terpenoid and/or secondary compounds. Spinifex resins are considered to be bio-organic polymers which belong to the thermoplastic class of bio-polymer. Therefore, below its 'glass transition temperature' (Tg), the resin is hard and brittle, but when the temperature reaches Tg, it becomes soft and malleable. (Mondal et al 2012a.)

5. Uses of Spinifex Grasses in the Classical Aboriginal Tradition

Aboriginal cultures evolved over many millennia in Australia prior to the arrival of Europeans and British colonization. The standard repertoire of architectural types used throughout the arid zone region consisted of windbreaks, dome-shaped shade shelters, fully enclosed weatherproof domes and storage platforms. Hummocks of spinifex grass (*Triodia*) were commonly used as a cladding on the timber-framed domes as well as for windbreaks and shade cladding. Dome forms included circular and oval plan, the bi-dome form, and multiple intersecting domes, collectively providing a set of modular options for enclosing space at heights most often 1.5 to 1.7m internally. (See Figure 3) The external dome forms were generated from a range of structural configurations depending on availability of tree limbs (length, thickness, shape), as well as preferred construction style, employing either cantilevered arches or single and double ridge poles on posts. Different structural styles were maintained by and enculturated within particular families and lineages to create regional sub-styles. Although spinifex grass was the dominant cladding material, others could be substituted or incorporated if available e.g. bark, tussock grass. Double cladding layers of spinifex interlocked by their root systems, were applied up to a metre thick. It is hypothesised that spinifex cladding has outstanding thermal insulation and water-shedding properties due to its open structure (interconnected air pockets) and resin content respectively. Layers of clay, mud or sand were applied over the grass to make composite cladding systems. (Memmott 2007: Ch9.)

Figure 3. Spinifex grass was by far the most widespread resource for the cladding wet weather domes in the Western Desert. This example at the Tomkinson Range near the Western Australian border. (Photo by Howard Hughes, Australian Museum.)

There is a general consistency in ethnographic accounts of Aboriginal resin manufacturing technology. At the end of the dry season, when the exuded resin had transformed from a sticky state to a flaky dry precipitate, selected clumps of spinifex with high resin content, were threshed to extract resin dust followed by winnowing to separate unwanted plant fragments. A carefully controlled heating technique was used to convert the resin dust into a sticky gum capable of being rolled into a ball.

Threshing occurred on a hard surface using a stick in order to dislodge the dried resin particles from the plant. The resultant mixture of resin, plant fragments and soil particles was winnowed to remove the bulk of chaff and non-resinous materials, though some of the latter may have been deliberately retained to raise the melting temperature of the resultant resin. The resin dust was subsequently heated over low heat until melted and coagulated, after which it was either used immediately whilst still warm and malleable for the purpose required, including hafting stone flakes to wooden handles to make spears, adzes, axes and knives. Once cooled the resin set hard. Alternatively, the produced warm resin was rolled into a suitable form such as a flat 'cake' (see Figure 4), or a ball on the end of a stick handle in preparation for later use, or for trade across the continent, in return for other artifacts or resources. (Gamage et al 2012:119-120.)

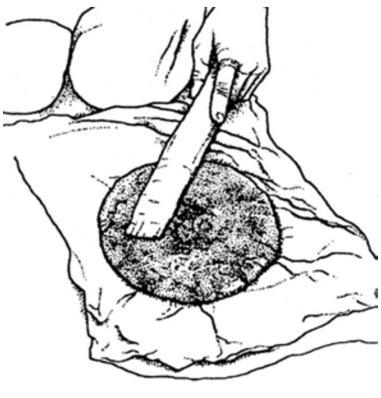

Figure 4. An Arrernte person paddling a cake of ankere, the resin from soft spinifex (aywerte). (Source: Henderson & Dobson 1994:142.)

Aside from hafting, *Triodia* resin was also used for mending cracks and holes in wooden carrying dishes, as a waterproofing agent, for decorative and ornamental purposes, including pins, beads, and necklaces, for use in both secular and ceremonial contexts. Other recorded Aboriginal uses of spinifex include leaf bunches burnt as torches to light the way in the dark, and the application of the burnt remains as a black colouring agent for body or object design. Arrerntic groups have used spinifex to make a wall of foliage across a shallow waterhole, which is then pushed across the pool to herd fish for ease of catching. Spinifex also has some medicinal uses, e.g., as a decoction to treat sores and itchy skin complaints, and inhalation of vapours for coughs, colds, flu and respiratory infections; also as a post-natal therapy. (Pitman 2010.)

6. Colonial Acculturation of Spinifex Cladding

The use of spinifex as a building material was adopted by British colonists in remote parts of the Australian frontier in the 19th century. For example in the Kimberley region, pastoral construction employed earth bricks manufactured from reconstructed termite mounds with chopped spinifex grass as a mechanical binding matrix. More unusual was spinifex in the construction of a reticulated bough shed (or 'bower shed'). Sandwiches 100mm thick were assembled of hummock grass restrained between two layers of wire mesh and then used as a cladding for roofs and walls over a log timber frame. Water was reticulated from a perforated pipe along the top of each wall to facilitate evaporative cooling as it dripped through the spinifex to provide tolerable summer living space. (Kelleher & Memmott 1997.)

Figure 5. Modern remote spinifex bough shed construction at the Dugalunji Camp, Camooweal, North-west Queensland. (Photo by Tim O’Rourke.)

Thatch (including grass thatch), has and continues to be a widespread construction medium on a number of continents although quality and durability vary from region to region depending on plant attributes and techniques. Thick thatched rooves are good insulators, but the penetration of dampness and enduring humidity are problematic. Dampness encourages micro-organisms and fungi which attract feeding insects. These in turn attract birds which remove material for nests, and a gradual break-down of the weather-proofing capacity results. To prevent the thatch acting as a sponge, rooves are steeply raked to ensure spontaneous run-off (Norton 1997).

In the international literature on the classification of thatching technologies, rigid thatching is differentiated from more supple plant stems with the former considered the most effective (e.g. water reeds) due to fast water shedding and locational stability resistant to wind damage (Norton 1997). The authors have found no mention in the literature of the potential of a water-repellent vegetal medium for thatching such as spinifex (see Oliver 1997). This supports our argument that the resinous secretion of selective *Triodia* species is a unique or at least rare plant attribute, one worthy of investigation.

In order to verify how spinifex achieves its efficient climatic response (rain shedding, wind deflection and thermal insulation), Aboriginal consultants were invited onto our project from the Alyawarr, Arrernte and Indjalandji groups in the central-east N.T. and central-west Queensland. These consultants have been employed to construct full-scale traditional shelters for building performance evaluation at the new Field Station being constructed at the Dugalunji Camp near Camooweal. Aboriginal trainees at the Dugalunji Camp clad all three with the resinous *T. pungens* in late 2008, albeit quite dry due to prolonged drought. The Indjalandji Elder, Ruby Saltmere demonstrated a distinctive technique of hitting the cladding with a stick to move the grass fibres into a downward facing habit for rain shedding. Environmental data loggers were installed on the first two traditional shelter forms and verified the capacity of these shelters to reduce diurnal temperatures. Despite a record wet season in early 2009, the *Triodia* cladding remained firmly in place for several years.

7. The Biomimetic approach to the project – Scoping Biomaterials

There is currently much interest in designing new materials that mimic particular properties of plants within their ecological systems. For example, self-cleaning materials have been developed from structures on the leaf surface of sacred lotus, and new composite fibres are being designed from plants to replace metal structures. Biomimetic theory and its application, bio-inspired design, derive concepts from natural systems and have potential to create new types of sustainable materials. The benefits of this approach in our project come from the linking of both ethnographic and ecological research with building and material sciences to create and test new building technologies.

As our current project evolves, such biomimetic theory may be useful for developing design solutions with spinifex; that is developing more robust, self-reliant, self-healing building technologies that can operate in an environment of energy poverty and water scarcity. We are investigating selected physico-chemical properties of spinifex grasses to evaluate the feasibility of producing novel and sustainable building technology products. Members of our team have commenced strands of research on bioengineering properties, plant physiology and entomological associations with spinifex, with a view to identifying potential biomimetic applications. Within a low-tech to high-tech spectrum of possible applications, a variety of products are being researched ranging from shade roofs, evaporative cooling walls, spinifex reinforced-earth walls and slabs, spinifex insulation batts (all at the low-tech end), to nano-whisker paper, resin to replace urea formaldehyde, coatings that may have anti-termite and ultra-violet screening capacities as well as bio-composite materials comprising fibre and resin (at the high-tech end). Our bio-engineering team (material engineers, chemists, botanists, architects, Aboriginal consultants) have examined the physical properties of both spinifex fibres and resin, including techniques of separating these components from the plant.

There is growing international commercial interest in developing polymers from renewable sources and the use of natural fibres for sustainable 'green' composite materials. A major problem with synthetic polymers derived from petroleum-based raw materials is their disposal. As landfill sites expand at an alarming rate, the quantity of solid plastic waste requiring disposal is becoming a serious global concern. Scientists are now constantly exploring for new cost-effective, bio-based, degradable polymeric materials which have market acceptability as commercial materials and can potentially decompose to harmless compounds when discarded.

Figure 6. Prototype for mulched spinifex insulation batt. (Photo by Tim O'Rourke.)

8. The Properties of *Triodia pungens* Resin

Triodia resin mainly consists of secondary metabolites (from plant metabolism) or compounds of terpenoid and/or phenolic compounds. It is therefore potentially an inexpensive, abundant renewable polymer feedstock in Australia (a raw material to supply or fuel a machine or industrial process). (Mondal et al 2012b.)

Thermal analysis of resin has been carried out by Thermogravimetric Analysis (TGA), Differential Scanning Calorimetry (DSC) and Dynamic Mechanical Chemical Thermal Analysis (DMCTA). TGA examines the basic components of the material by mass, defining the temperature at which each fraction (constituent oils and volatiles) vaporizes. DSC establishes temperatures at which the material experiences changes in phase; from solid through a glass transition to a liquid state. This makes it possible to predict a materials stability at a given temperature in a real application. DMTA takes this a step further, relating changes in actual stiffness and strength figures to the working temperature range of the material. Different permutations of spinifex composites, raw materials and traditionally prepared composites using Aboriginal manufacturing techniques, can be compared using these analysis methods to provide a detailed understanding of the way each behaves.

We have determined pure spinifex resin to be hydrophobic and thermoplastic in nature; like most commercial plastics, it can be repeatedly softened and moulded. It undergoes a glass transition (Tg) between 40°C and 80°C, crystallising from 110°C and melting at 165°C. Thermal history and the quantity and type of impurity affect these figures, and by controlling these variables we are able to manipulate the properties of the resin. Both thermal degradation and glass transition temperature of resin samples increased when resins were heat treated owing to the thermally induced reaction between the functional groups. Reinforcements of fillers in the resin matrix further increased glass transition temperature and improved thermal degradation properties because of the network structure formation by interaction of resin functional groups and mineral compounds in the resin matrix. This increase in glass transition temperature was achieved in the traditional Aboriginal technology by the retention of a small proportion of chaff, mineral deposits and possibly sand after winnowing. Repeated heating of the resin removes low molecular weight volatiles, and the Tg threshold can be raised as high as 50°C. (Mondal et al 2012a.) Raising the glass transition point of the resin is a priority, as this will make the resin more stable at room temperature and more suitable as a component of a composite material for building applications.

Although few, if any plant resins have been used to generate commercial polymers, our research suggests this avenue is worth exploring. For example, for some 40 years, applied research has been carried out with increasing interest on natural-based renewable wood adhesives in the timber industry to be used in re-constructed wood products, such as particle board, plywood, veneers, glue-laminated beams and columns. One of the holy grails of reconstructed wood products research is to find a competitively costed ‘green’ glue to replace urea-formaldehyde glue, which is a proven carcinogen. There has been commercial interest to see if *Triodia* resin can fulfill this role.

9. Renewable Resource-based Polymers and Biocomposites

Bio-composite products are made up of an individual ‘polymer matrix’ and ‘fibre reinforcement’ components which remain bonded together by physical or chemical interactions, but retain their individual physical or chemical identities. The properties of composite materials, in general, are superior in many respects to those of the individual components. Still, most composites are made with synthetic polymer as the matrix phase, and synthetic, metallic or glass filler as the dispersed phase. In contrast, our research team is researching both *Triodia* resin and fibres as potential building blocks for renewable polymers and/or composite materials, extending the existing Indigenous uses of *Triodia*. We explore the preparation of polyurethanes from spinifex resin biopolymer. For example, we know that heating and kneading of *T. pungens* resin as practised in Indigenous culture increases its softening temperature, but we do not yet fully understand the chemistry or mechanisms involved. We have been preparing cellulose nano-whiskers from *T. pungens* fibres and are investigating whether the resultant materials have a unique morphology owing to the fact that *Triodia* is a xerophyte (arid-area plant requiring little water) which could be expected to display different properties to mesic plant species (moderate water content) from which most biomaterials are derived. (Gamage et al 2012:121.)

We have successfully prepared biocomposites comprising almost 100% *Triodia* matrix and reinforcement. Chemically modified *Triodia* resin was employed as the matrix, and chemically cleaned and cryoground *Triodia* grass fibres were employed as the dispersed reinforcing phase. One of the major problems for making biocomposites is to obtain effective mechanical properties. The stiffness and strength of the *Triodia* resin is quite low compared with modern day thermoplastics such as polyesters and nylons, but its properties may be improved by reinforcing with *Triodia* fibres. Good mixing and dispersion of fibres, together with strong bonding or adhesion between fillers and the matrix are critical performance requirements to achieve useful mechanical strength for biocomposite. (Gamage et al 2012:121-122.)

10. Triodia Fibres as Reinforcement for Biocomposite

"Natural fibres can serve as substitutes for conventional reinforcement materials such as synthetic, glass or metallic fillers, and offer numerous advantages including greater availability, renewability, low cost, biodegradability, and high degree of flexibility during processing, stiffness, and a relatively low density for light weight composite applications. Plant fibres such as kenaf, flax, jute, hemp, sisal, coir and ramie are widely used for reinforcement of thermoplastic and thermosetting matrices in order to enhance mechanical and other functional properties…; stem and leaf fibres of the stiff non-resinous species of *Triodia* could potentially be used in a similar pattern." (Gamage et al 2012:121.) The leaf fibres of *T. pungens* and *T. longiceps* are low (135 MPa) and medium (409 MPa) in tensile strength respectively, when benchmarked against high-performance natural fibres (>600 MPa) such as sisal, flax, hemp and stinging nettle. (Flutter 2009.)

Unmodified cryo-ground spinifex grass fibres have been used as a reinforcing phase in thermoplastic polyurethane prepared from spinifex resin biopolymer. The morphology, thermal and mechanical properties of the prepared composites were characterized using a battery of laboratory techniques. The results obtained indicate that interfacial interaction between the spinifex grass fillers and the polyurethane matrix occurs, and that the ground spinifex cellulose fillers act a promising reinforcement for the relatively weak polyurethane matrix synthesized from renewable spinifex plant resin products. The bio-composites based on renewable spinifex resin based polyurethane and spinifex grass, which is cheap and abundant in Australia, could be potentially useful in some material applications, particularly if the T_g and strength of the polymer matrix can be further increased for higher strength of resultant bio-composites.

11. The Osmosis properties of Triodia Pungens

There are clearly further biomimetic prospects to examine besides the use of resin in compound material forms, and the leaves as cladding. A most inspiring and challenging example is the anatomy of the spinifex stalk and leaf itself, and whether its cross-sectional and longitudinal properties can provide inspiration for the thermal design and humidity control of an architectural structure in an arid climatic setting. Of particular interest here is the exudation cycle of the resin on the surface of the soft spinifex species and whether it functions to protect against excessive moisture loss from its spongy storage mass, whilst simultaneously allowing an osmotic process of gas exchange for photosynthesis. To better understand the ecological function of the resin, one of our team is carrying out morphological observation of the resin on the leaf and stem surfaces using scanning electron microscopy and further experiments in gas controlled environments, to determine how gas permeability relates to the morphology of the resin coverage.

12. The Challenge of Sustainable Harvesting

By combining traditional indigenous knowledge about *Triodia* grass and resin applications, preparation, structure and properties with controlled laboratory purification, modification and testing, we are in the process of evaluating the potential for developing *Triodia* resins and fibre as future renewable materials. Our extended biocomposite research in this area could find applications in advanced functional material applications such as building and automobile industries, however if such potential is to be realised we also need to substantially increase our understanding of the ecology of *Triodia* grasslands.

If harvesting of *Triodia* grasslands is to be considered, degradation has to be avoided and long-term sustainability achieved. Commercial harvesting licenses will not be issued by Australian governments unless there is a sound scientific case presented on how best to perform sustainable harvesting. Another branch of our project thus addresses the different methods and optimal times of different modes of spinifex reproduction and propagation, including the relevance of burning the grass. We are also investigating how localised burning and harvesting of *Triodia* could be an adaptation to climate change that has sustainable ecological and economic benefits (carbon trading).

Figure 7. Aboriginal students from North Queensland attending a pre-vocational course hosted by the Dugalunji Aboriginal Corporation in Camooweal, conduct a controlled winter burn of University of Queensland spinifex plots as part of experimental harvesting research, August 2008. (Photo by Susanne Schmidt.)

13. The role of the Dugalunji Camp in the Project

Our spinifex project has been developed in partnership with the Myuma Group comprised of the Aboriginal Traditional Owners of the Camooweal/Upper Georgina River basin (the Indjalandji-Dhidhanu peoples). Myuma operates the Dugalunji Camp, with a total maximum accommodated population of 80 persons, and which is a recycled, upgraded and landscaped former Main Roads Camp situated on 1.5 hectares in a remote semi-arid setting of red sand, spinifex grass and open eucalypt woodland. The Dugalunji Camp (or village) currently operates as a very successful business facility for Aboriginal enterprises (inc. road and mine construction), cultural heritage surveys, a keeping place, and the training of Aboriginal people. (Memmott 2009.)

Dugalunji sees the current spinifex project as a two-way educational partnership. They wish to play a cooperative role, bringing to the project their regional Aboriginal geographic knowledge, bush teaching skills, and human and infrastructure resources. They wish to promote learning opportunities for local Aboriginal people from UQ researchers and students, fostering a mutual appreciation of the cross-cultural knowledge bases. The Dugalunji Corporation has also recently supported the establishment of an Arid Zone Field Station financed by the University of Queensland which will be built at the Dugalunji Camp in 2013-14, and which will be used by the researchers as a vehicle for piloting the use of spinifex in low-tech building solutions.

A key architectural problem in the Dugalunji Camp is how to design fireproof spinifex building components to supplement the pre-fab building structures. The one storey, pre-fabricated, transportables or pre-fab ‘dongas’ typically used in remote mining camps in Australia are not well designed for passive climate control in the warm arid winter and hot monsoonal summer climate, being without overhangs, insufficient insulation and totally reliant on high-energy consuming, wall-unit air conditioners in every room. The design challenge is to supplement the pre-fab core with additional climate filters of low-tech, low-cost, local construction and to replace the unit air-conditioners with a solar powered solution.

14. Conclusion

A strong commitment to Aboriginal culture and Law as embellished in sacred histories, permeates through the Dugalunji Camp on a daily basis via a number of mechanisms and behaviours that include visitation and residence of regional Elders, the delivery of cultural heritage services and cultural induction programmes to regional industries by Myuma and workshops on strengthening cultural identity for prevocational trainees. There is a unique symbiotic relationship between the practice of Aboriginal Law and the practice of commerce in the Dugalunji Camp whereby the two are mutually supportive of one another, generating a strong consumption of Aboriginality in the way that day-to-day ‘business’ is run by Myuma. This consumptive style extends to the use of space, architecture and landscaping in the camp.

To this unique and receptive Aboriginal cultural setting, our research team has been privileged to develop and grow our spinifex project. Despite spinifex being a practical and symbolic component of traditional Aboriginal culture, there has been little interest to date from wider industry in the use of this grass as a source of biomaterials. We are only partially progressed in our study to determine if and how *Triodia* grasslands can be harvested sustainably, but note that our research is designed to fill obvious gaps in the knowledge of *Triodia* biology and thereby ascertain whether small-scale industries in remote areas could sustainably use *Triodia* grasslands.

We expect that further systematic study of the morphology and thermal behavior of spinifex resin and composites, that builds upon our combination of low-tech and high-tech research to date, including the enhancement of the properties of the resin, will make a significant contribution to the effective processing of *Triodia* biopolymer for developing novel advanced biopolymer-based materials and perhaps catalyse a regional bio-processing industry.

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