Australian Industrial Hemp Conference 2018

Conference Proceedings

By Stuart Gordon

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Foreword

With the recent changes in the regulatory environment AgriFutures Australia has identified hemp as important emerging industry. Therefore the Australian Industrial Hemp Conference comes at a particularly important time for the Australian industry to coordinate and to develop business models that will unlock the potential of this crop.

From Hempcrete, to beer, hemp fibre products, medicinal uses and seed, the dynamics of hemp business models vary widely. The Australian Industrial Hemp Conference provided an opportunity for interaction and for presentation of up to date information. These proceedings will be useful for those interested in hemp as a crop or more widely in businesses along hemp value chains.

AgriFutures Australia values the collaboration with CSIRO and Stuart Gordon in working with presenters to prepare these proceedings. We commend them to those interested.

This report is an addition to AgriFutures Australia's diverse range of over 2000 research publications. It forms part of our Emerging Industries arena, which aims to establish commercially viable and sustainable industries.

Most of AgriFutures Australia's publications are available for viewing, free downloading or purchasing online at www.agrifutures.com.au. Purchases can also be made by phoning 1300 634 313.

John Harvey
Managing Director
AgriFutures Australia

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Executive summary

The idea for an Australian industrial hemp conference came from Robert Bell following a small forum organized by the Industrial Hemp Association of Victoria (IHAV), CSIRO and Regional Development Victoria (RDV) in Waurn Ponds in February 2017. Victoria was the first state in Australia to legislate and allow industrial hemp production under regulation (in 1998). Since then other states have followed with similar legislation. However, production volumes in Australia are still small and so it was the view of the forum that more needed to be done to promote its expansion.

The key strengths of hemp as a viable crop identified at the February forum were its versatility in production and value as a food source. The crop can be grown productively across a wide range of latitudes and produces a range of valuable food and material products, although the full value of its products remains to be exploited. Hemp was seen as an excellent rotation or break crop, although lack of information around seed and variety availability for different regions and production systems were seen as barriers, along with regulation of the crop's tetrahydrocannabinol (THC) levels.

The approval by the Council of Australian Governments of the proposal to permit the sale of low-THC hemp seed (foods) on 12 November 2017 removed a very large barrier to this industry. The removal has already propelled production of hemp grain and, will hopefully, promote production of other hemp farm products, such as fibre and shiv.

A committee of participants from the February forum was convened to help organize the Conference. The committee of Robert Bell (Robert Bell Projects), Charles Kovess (Australian Industrial Hemp Alliance (AIHA)), Lyn Stephenson (IHAV), Erwan Castenet (Deakin University), Mac Fergusson (RMIT), Menghe Miao (CSIRO) and Stuart Gordon (CSIRO) met for the first time in June 2017. One of the underlying themes of the Conference was that of collaboration. It is imperative for any new industry to develop successfully that information be openly shared.

Two hundred and thirty six delegates, including a large number from overseas, were testimony to the burgeoning interest in this crop and its products. From the outset the committee recognized expertise from overseas would be important to provide the latest information on crop production, varieties and product processing. And hence, experts from Canada, New Zealand, the USA and Europe were identified and invited, as were a host of local experts and regulators. The committee would like to thank the 38 speakers, especially those from overseas and interstate, for the time they took in their busy schedules to visit Geelong to extend their knowledge.

The committee remains very grateful to the sponsors who took a chance on the Conference and without whom the Conference would not have been possible. Key (foundation) sponsors of the inaugural event were AgriFutures Australia, Ecofibre, Midlands and Australian Cannabis Laboratories. The committee is also indebted to the contributions of the AIHA, the IHAV, AusBiotech, Geelong City Council, RDV, CSIRO Manufacturing, Deakin University and RMIT.

It is with great enthusiasm the organizing committee commends anyone interested in industrial hemp to join their state and national associations to access information on growing hemp, processing hemp products and/or advocate for research into the crop and its processing. The committee is confident the success of this first Conference will assist in hemp being recognized as an 'emerging industry' in Australia and thereby hasten the impact of this obviously valuable crop.

The decision for this Conference to be a biennial event is welcome and the committee looks forward to assisting in co-ordination of the next Conference in 2020.

We look forward to seeing you there!

Wednesday, 28 February 2018

SESSION 1
Industrial Hemp: Perspectives on an Emerging Industry

Chair: James Vosper, President Australian Industrial Hemp Alliance and the Industrial Hemp Association of NSW

New and Emerging Plant Industries; the Australian Industrial Hemp Industry
David McNeil, Professor of Agricultural Science, University of Tasmania and Chair of AgriFutures Australia New and Emerging Plant Industries Panel

Industrial Hemp in North America: Production, Politics and Potential; perspectives for Australia
Jerry Cherney, E. V. Baker Professor of Agriculture, School of Integrative Plant Science, Cornell University, USA

New and Emerging Plant Industries: The Australian Hemp Industry

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Keywords: new crops, industry development, analytical tools, market analysis, value chains.

Abstract

Developing new crops in a region is expensive, time consuming and has a high risk of failure. However, in can be highly profitable for participants from growers to processors to final sellers and users. The New and Emerging Plant Industry Panel I chair has the task of advising AgriFutures Australia in their goal to establish R&D partnerships with new and emerging industries to help them expand profitably. The goal is to generate 5 new industries worth $10 million pa in the next 5 years as well as have other industries following on in the future.

New plant industries are highly variable. Some may simply be new to growers in a particular region. Others may be completely new and novel with no corresponding industry producing the product anywhere in the world. Some are highly niche and quality dependent (e.g. whisky in Tasmania) while others are broadly commodities (e.g. sesame). Consequently there is no single method of knowing whether an industry can succeed in the future. Thus, globally evaluation protocols have been developed to: a) Establish the likelihood of success of a new industry. b) Understand where to expend resources to maximise chance of successful development. c) Clearly understand the development target to aim for. d) Evaluate among competing possibilities. e) Clarify advantage, suitability and issues for industries. The protocols frequently evaluate similar characteristics differing in emphasis across financial, agronomic, marketing, social, environmental, industrial, competitive, regulatory and historical situations surrounding the crop and develop potential targets for improvement of industry development. This talk will demonstrate the use of some of these protocols for a range of crops and provide insights into how they may be used for expansion of the industrial hemp production industry.

Introduction

My first new crops research was in 1973 evaluating (then highly unusual in Australia) highly coloured sweet potato varieties as a trainee with the NSW Dept. of Agriculture at the Alstonville Tropical Fruit Research Station. Since then I have worked on diverse crops with varying levels of 'newness' encompassing breeding, value chains, agronomy, disease and other issues. The type and level of 'newness' (Table 1) affects the difficulty and form of developing a new industry. My research has covered whatever seemed a major issue for the development of the new crop. This has met with various levels of success and failure but has also created personal understanding of how to improve chances of successfully developing an industry.

Many diverse analytical methods aim to help predict success, establish priorities and categorise new industries. Most use similar components with variable emphasis associated with specific goals and the 'newness' or type of crop. None predict certain success. Rather they force participants to dispassionately review all elements that may be critical advantages or issues. They thus may limit excess 'blind passion' for a crop creating more carefully thought through 'passion' in the face of obstacles which is needed for success. This paper will not deal directly specifically with hemp. Others can supply greater specific details, I shall endeavour to use my personal research and consequent opinions to provide the tools into which information on hemp can be interposed to assess its potential and needs and generate industry development plans.

Table 1. Some types of 'newness' suggested by my personal experience. Groups indicate increasing need for industry development. Hemp would seem to be between Groups 1 and 2.

Group	New to	Example	Location
1. Well developed elsewhere	Grower	Lupins	NSW, 1980's
	Region	Apples	S Island NZ, 1990's
	Environment	Walnuts	Guangxi, China, 2000's
2. Partially developed elsewhere	Mechanisation	*Plantago ovata*	N Aust., 1980's, 2010's
	Marketing system	Blood oranges	UK, 2010's
	Specific use	Cut flower gentians	NZ, 1990's
	Variant types	DuPuis lentils	Victoria, 2000's
	Potential consumers	Orange sweet potatoes	Australia, 1970's
3. Minimally developed	Undeveloped use	Kakadu plum	Australia, 2010's
	No real prior use	Plant phages	NZ, 1990's

Forms and purpose of analyses
AgriFutures Australia is an R&D investor and manager seeking co-investing industry partnerships with committed people to develop new and emerging industries using their available resources that will make a real difference in the Australian agricultural landscape. To this end they have set a goal of five new industries turning over $10 million pa by 2022 with industry panels in place to listen and provide advice to AgriFutures Australia.

Global market scan
Desire to develop a new industry can arise from an existing passion, a need to assess a presented opportunity or a need without a preselected option. AgriFutures Australia has commissioned global market scans to review possible industries and generate assessment tools to evaluate possible new industries by comparison with others. Euromonitor [1] investigated over 50 potential new industries for Australia (including hemp) to produce a final list of 10. Their global analysis included: An overview of the product, what it is, where currently produced; Demand factors and growth drivers; Major and/or interesting uses/applications; Relevant trends; Potential opportunities and/or threats; Perceptions of the industry. Descriptions included; Uses and applications, Issues/challenges, Supply, Global production, Current Australian landscape, Retail market prices, Illicit trade or other issues, Demand, Consumer perception, Retail market value, Legislative and Regulatory Environment, Trading channels. They did not look at specific existing and potential relationship with Australian industry nor did they restrict themselves to any level of development or 'newness'.

Thus options suggested ranged from developed global crops (e.g. sesame) to highly novel options (e.g. moringa). The next stage would be to determine how to achieve the commercialisation of the opportunity. This is detailed more in the Coriolis [2] analysis, which scanned a broad range of industries and selected 53 in the $1-$10 million pa range in Australia that would be suitable targets for achieving the AgriFutures Australia target. These were reduced to the nine 'best' (including hemp seed) based on achieving both qualitative and quantitative high scores. Their 'Qualitative Assessment' included: use of trade data, future turnover estimates, summary of the opportunity, drivers of growth, value added opportunities, competitors, risks and sensitivities, what you need to believe for it to succeed. Their 'Quantitative Assessment' included: total global value, growth in value and trade, value density of the product, price stability. Thus their selections did not include high degree of 'newness' industries but centred on opportunities with substantial background development. They suggested high potential emerging industries shared one or more of: health benefits, emerging cuisine, hot and on trend, premium. They also detailed the next steps for the opportunity, developing the commercial case and finally attracting investors. An independent scan conducted for the South Island of New Zealand [3] in 2002 targeted industries ready for immediate development as profitable options for investors. Two options were identified. 1) Local niche opportunities with significant competitive market advantage. 2) Substantial global industries with; a) stable world price, b) large market compared to expected expansion, c) competitive production advantage (better quality, accessible market, cheaper price). This also required development at scale with a capital base to finance the full production and marketing chain, including overhead and fixed cost loading. The smaller scale 1st option creates individual businesses rather than global industries but may eventually be a stepping off point. They reviewed several industries and times for potential (Table 2). Correct timing was critical as crops are not ready for direct development as profitable industries until adequate research, development and extension has taken place (e.g. kiwi fruit).

Table 2. Industries considered by [3] for rapid profitable development in the South Island of NZ in 2002 relative to their status for the core postulated requirements. Y = yes, N=no.

Option	Stable world price	Established world market	Competitive production advantage
Ostriches		N	
Kiwifruit			
1990	N	Y	N
1999	?	Y	Y
Blackcurrants			
1999	Y	Y	?
Sheep milking	Y	Y	?
Goats			
Venison			
1990	N	N	Y
1999	Y	Y	Y
Cut flowers	Y	Y	Y
Hazelnuts	Y	Y	Y
Dairying	Y	Y	Y
Tulips	Y	Y	Y

Development of the Industry

Having established an opportunity it must be developed into a viable industry. In 2009, the RIRDC [4] suggested seven generic 'Critical Success Factors for New Rural Industries'. These were:

1. A primary focus on customers and marketing.
2. A viable source of competitive advantage in the target market.
3. An industry-wide capability to consistently deliver a product of the required quality.
4. A well-functioning supply chain.
5. An effective leadership and strategic planning across the industry.
6. A business proficiency and access to sufficient capital.

7. A well-planned, well-managed, adequately funded research and development (R&D).

Additionally they suggested benefits of information sharing and cooperation for creating critical mass and economies of scale. They cautioned the need to be realistic about the difficulties of implementing efficient production systems, quality codes, commercialising of new products, costs and time scales in creating the industry. The RIRDC proposed stages in the development of an industry from embryonic to professional investor stages and postulated the specific needs at each stage alongside their seven critical success factors. Subsequently, McNeil [5] using observations on specific industry developments postulated some similar general characteristics. Emerging industries need to develop as complete industries with the whole social context clarified and accepted in addition to the industry agronomy and finance. Priorities need establishment across all aspects to foster development and capture advantage (Research, Development, Extension, Education, Policy and Management). In all cases there needs to be significant investment of time, finance, effort and commitment (Figure 1).

Figure 1. Graphical depiction of an established and new industry value chain; a) critical issue for new industry, b) region of high competitive advantage (from [5]).

Typically an established viable industry in an old region functions well in all steps of the value chain due to experience, scale and history. A new industry establishing elsewhere may fall slightly short in many steps, but two critical steps stand out; a) steps which are well below requirements (e.g. processing, locally adapted varieties) and b) steps of significant competitive advantage that make the struggle in other steps worthwhile (e.g. superior quality, supply reliability/season, disease free). It is on these two steps that I suggest major efforts should be expended to create a viable industry (Figure 1). Kahan [6] postulated one need & seven barriers to development of entrepreneurial farm enterprises (Table 4), with my first attempt to include hemp seed into the analysis. McNeil [7] developed this into a more complete analytical tool and looked at walnut industry development of 3 global emerging industries in NZ, Australia and Guangxi province, China (Table 5).

Table 4. Evaluation of the fit between the walnut industries in three regions and Kahan's [6] one need & seven barriers to development of entrepreneurial farm enterprises. My interpretation of possible situation for hemp seed in Australia has been added for consideration.

Barriers	NZ Walnut	Australia Walnut	Guangxi Walnut	Australia hemp seed
Entrepreneurial spirit (need) at an individual or cooperative level	++	++	++	++
Poor or absent infrastructure	Process ± —> ++	Process ± —> ++	Process (roads) -- —> ++	Process ± —> ++
Unsupportive law and regulations	± —> ++	± —> ++	± —> ++	± —> ++
Lack of financial support	--	± —> ++	++	?
Social barriers	++	++	++	?
Lack of training facilities	++	++	++	±
Lack of support services and trained extension staff	±	±	++	±
Marketing constraints	++	++	++	+

++ Not an issue, ± —> ++ becoming less of an issue, ± an issue, -- a major issue

Table 5. New Industry assessment tool [7]. Each measure is assessed as meeting need, less than optimal or of significant concern. Where values meet need they suggest a viable industry. Issues that do not meet need indicate areas for research, extension or policy development.

Description of industry	Measure	Need
Size	Present value of the industry $/ha/employment	High
Expansion rate	Change in size per year	High
Value retention	Proportion good investments from historical investments	High
Profitability	Level of return on present and future capital/labour/resources	High
Entrepreneurial businesses	Existence	Many
Quality of Entrepreneurship and Innovation	Number & diversity of products, branding, vertical & horizontal relationships in key businesses	High
Potential size	Possible future value of the industry $/ha/employment	Larger
Risk management		
Production risk	Ability to sustainably produce a crop in most years due to adequate climate, production & environment knowledge and needed materials (e.g. varieties)	Adequate knowledge
Financial risk	Likelihood of losing existing capital	Low
Market risk	Certainty of a market where industry has an advantage	High
Societal risk	Presence of licence to operate issues, i.e. low community support	Low
Government support	Subsidy, tax/policy/licensing etc. systems support, RD&E support	High
Entrepreneur access/control		
Land/processing capability	a) Existing owners keen to invest in capability	High

	b) New owners keen to buy and develop capability	High
	Overall for a) and/or b)	High
Market	Unfilled opportunities visible	Certainty
Finances	Risk capital available	
Societal value	*Issues with Entrepreneurs*	Low
	Availability of Entrepreneurs	High

In addition to the needs for industry development, the nature of the industry development was found to vary among industries and locations. Table 6 shows 4 types of development I have observed mainly separated by the source of funds and subsequent growth rates and integration.

Table 6. Different types of walnut industry development observed by McNeil [7].

	NZ Walnut	**Australia Walnut**	**Guangxi Walnut**	**Australia Hazelnut**
Players	Many small private investors	Few large/ corporate investors	Govn./many small private investors	Large corporate upstream investor
	some Co-op	some Co-op	many Co-op	subservient
Businesses	Small	Large	Small	Large/medium
	Private – resources	Corporate - capital markets	Govt. /Private resources	Corporate
Vertical integration – main businesses	High	Low shifting to high	Low	High
Growth rate – Primary tier	Low	Moderate	High	High
Growth rate – secondary tier	-	Low	Low	Low

Conclusion

A broad range of new industry analytical methods have been presented based predominantly on experience with a range of industries spanning many global regions. I suggest those who really know the industry need to realistically assess Australian hemp options using some of the tools presented. The goal is not so much to evaluate potential for success, but rather to focus the industry on impediments and advantages to enable best use to be made of the limited resources that are available. Where does the present industry lie across the dimensions presented in its own right and relative to others? Using this knowledge those involved need to then commit to developing the total industry and seeking productive partnerships. This commitment needs to continuously reassess its appropriateness and keep answering the question. Will this action achieve the desired goal? Do we have the time, resources, energy, people/actors and desire to continue? In short, 'how do we get where we wish to be from where we are'? Is this the best action to speed us on the way? Do we have the correct group to do it?

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Industrial hemp in North America: Perspectives for Australia

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Keywords: North America, federal policy, cannabidiol, economic value, niche market

Abstract

Industrial hemp was grown for fiber in the USA and Canada until the late 1930's, when hemp was banned in both countries because it could not be distinguished from marijuana. Canada began issuing licenses for commercial hemp production in 1998, and hempseed fit in well with Canada's large oilseed industry, most of the current Canadian hemp production is hempseed. Licensing and regulations for hemp in Canada have not been an impediment to Canadian farmers over the past 20 years. A number of states have recently approved the regulated production of industrial hemp in the USA, although federal policy still treats hemp and marijuana as the same plant, classified as a Schedule 1 controlled substance. Throughout most of history, hemp production has focused on fiber. There is a stable niche market for hemp fiber products in the textile industry, but it is not clear if the market will expand greatly in response to various hemp building construction products or biocomposites now available. A number of economic analyses of a potential hemp industry in the USA have been conducted over the past 20 years. Studies cited uncertainty about long-term demand and the potential for oversupply, which are typical concerns for the introduction of any new novel field crop.

Hemp has far more potential as an oilseed crop than as a fiber crop at this time. Dietary advantages of hempseed and hempseed oil are quickly gaining acknowledgment in North America. Many companies in North America are currently investing in cannabidiol (CBD) research, production, processing, and marketing. It may be a feasible strategy to grow conventional oilseed cultivars for a dual crop, collecting both seeds and CBD, but more research is needed. CBD production has the potential to greatly surpass the combined fiber and oilseed markets, if regulatory agencies take a reasonable approach when addressing CBD. Potential economic value of CBD has been estimated to exceed that of medical and recreational marijuana combined. It is anticipated that the market for organically-produced hempseed will expand greatly, and relatively local production is usually required to meet organic certification standards. The oilseed hemp industry is most in need of high-yielding cultivars to increase economic competitiveness, an average productivity of around 4 tonnes/ha is required. This is about twice the present productivity of oilseed hemp in North America. High seed losses also need to be addressed with improved harvesting technology and breeding to minimize shattering losses.

Introduction

With the federal legislation to allow consumption of hemp seed, Australia is poised to greatly expand industrial hemp production. It may be helpful to review how this process has unfolded in North America.

Industrial hemp was grown for fiber in the USA and Canada until the late 1930's, when hemp was banned in both countries because it could not be distinguished from marijuana [1]. A brief revival of hemp fiber production occurred during both World Wars, primarily for maritime uses.

Canada began issuing licenses for commercial hemp production in 1998. Hempseed production fitting in well with Canada's large oilseed industry. Hemp production in Canada steadily increased until 2014, with some setbacks (see Figure 1).

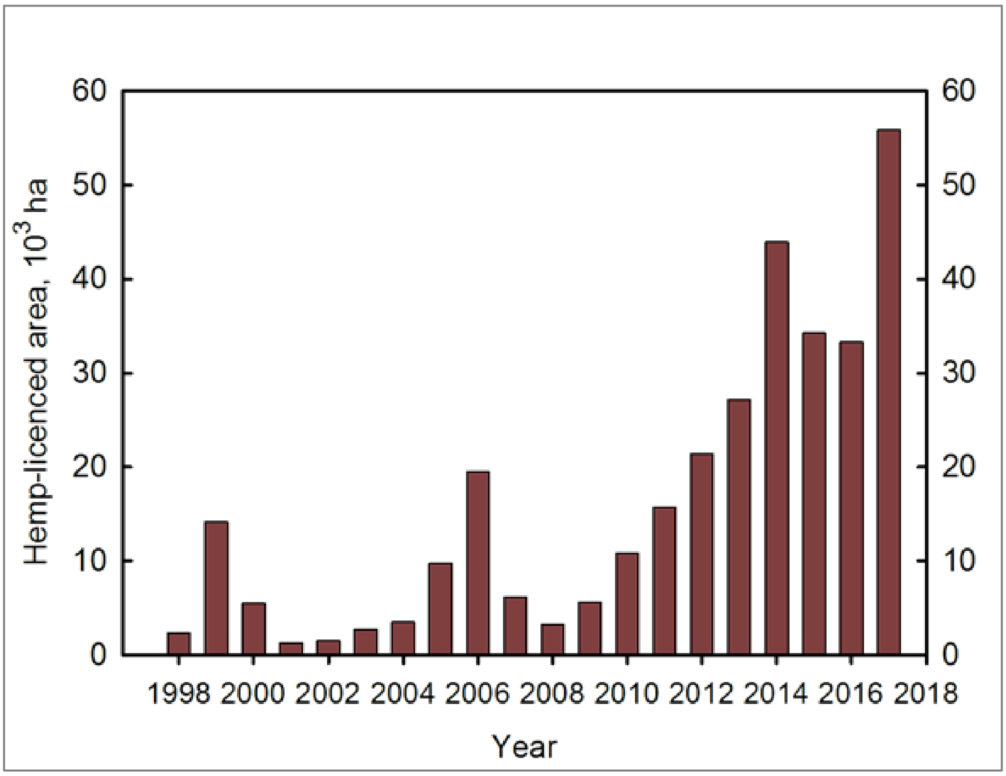

Figure 1. Hemp-licensed area (ha) in Canada since permits were available in 1998 [2].

Production of hemp fiber increased in anticipation of fiber processing facilities, but such facilities never materialized. There was no market for the raw fiber and production temporarily crashed. Most of the current Canadian hemp production is hempseed. Licensing and regulations for hemp in Canada have not been an impediment to Canadian farmers over the past 20 years.

Hemp cultivation in the USA is contingent on approval of state agencies and the US Drug Enforcement Agency, since hemp remains a federally-controlled crop. Both Canada and the USA use the threshold concentration of 0.3% THC (tetrahydrocannabinol) to legally distinguish hemp from intoxicating Cannabis relatives. Approximately half of the states in the USA have recently passed laws permitting farmers to be licensed to grow hemp. States differ in their specific regulations.

Hemp readily escaped cultivation over 100 years ago and it gradually spread across most of North America, becoming known as "ditchweed". There was a major investment by law enforcement in eradicating wild hemp, even though there was no essentially risk for producing intoxication. Federal USA law continues to treat hemp and marijuana as the same plant, classified as a Schedule 1 controlled substance.

Principal Uses for Hemp in North America

Fiber

Throughout most of history, hemp production has focused on fiber [3]. The more valuable long outer hemp fibers (phloem or bast) are separated from short inner fibers (xylem or hurds) by the process of retting, which can be done in-field, by using water, or with chemicals. Water retting is very undesirable from an environmental standpoint and is not allowed in most countries. Bast fibers are used for papers, textiles and automotive applications, while hurd fibers often are used for animal bedding and construction materials. Hemp has been replaced by other natural and man-made fibers for most uses, and worldwide hemp production for fiber has been relatively stagnant for the past 20 years. There is a stable niche market for hemp fiber products in the textile industry, but it is not clear if the market will expand greatly in response to various hemp building construction products or bio-composites now available.

Oilseed

Although hempseed has been used as food for many centuries, oilseed cultivars of hemp have only relatively recently been bred in Europe and Canada [4]. Hulled hemp seed has become popular for human consumption, and hempseed imports into the USA (primarily from Canada) have increased dramatically in recent years (Fig. 2). Vegetable oil extracted from hemp seeds cannot be used for cooking or frying, and is best used as a fresh salad oil. Because the fatty acids in hemp seed oil are mostly unsaturated, it has a relatively short shelf life, and requires dark containers and refrigeration.

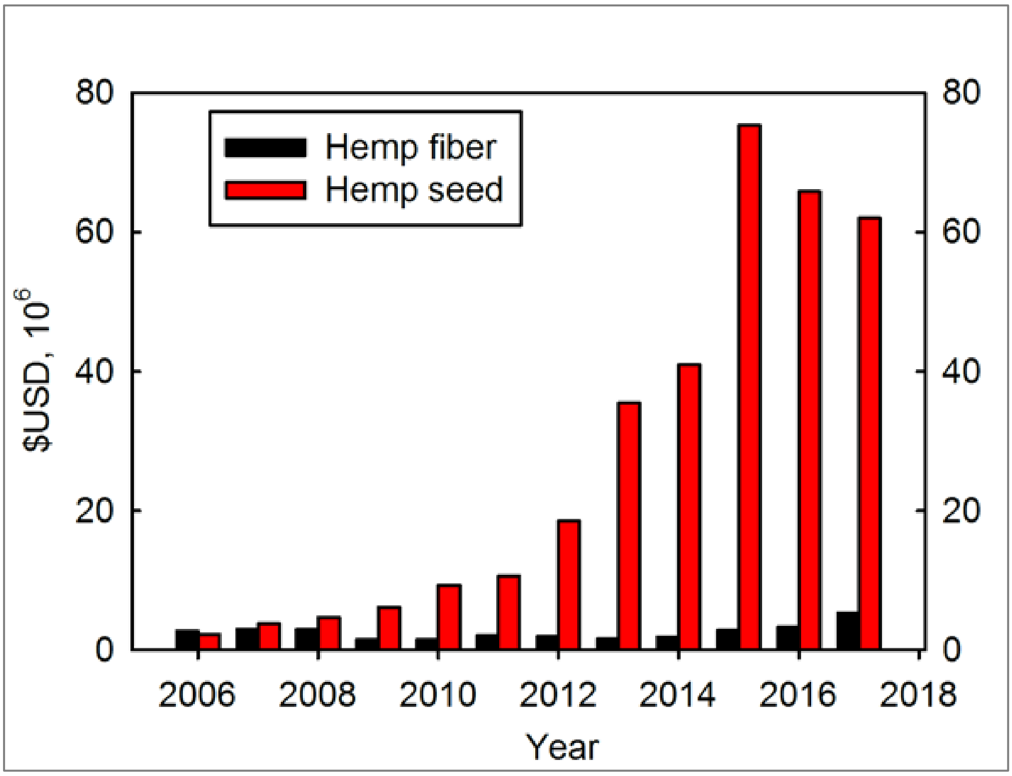

Figure 2. Value (USD) of USA imports of hemp products, 2006-2017 [5]. Seed category includes whole seed, oil and seed oilcake. Fiber category includes raw and processed fiber, woven fiber and yarn.

Oilseed hemp is currently not economically competitive with the other edible vegetable oils. Higher seed yields of the crop are likely through breeding and improved agronomic practices, which would make the crop more competitive. In North America, hempseed is primarily used as human food, while in Europe the seed is mainly used as livestock feed. Hempseed oil is considered to be a very healthy food, rich in omega-3 and omega-6 fatty acids with an optimum ratio of 3 to 6, and also contains other fatty acids of dietary significance [6].

Hemp has an indeterminate inflorescence such that individual seeds ripen over time. Also, hemp seed starts to shatter relatively soon after ripening. Therefore, hempseed yield is maximized when about 70% of the seed is ripe, with significant seed losses in the field. Improved harvesting technology is required. The main concern with hempseed production is yield. Average North

American yields of about 2 tonnes/ha need to be doubled to compete economically with other oilseeds [7].

Pharmaceuticals

Cannabinoid compounds (terpenophenolics) are produced in epidermal glandular trichomes (bulbous hairs), mostly in flower parts and on young leaves in *Cannabis*. Over 100 cannabinoids are found in *Cannabis* and only a few are present in useable quantities, with the primary two cannabinoids of interest being tetrahydrocannabinol (THC) and cannabidiol (CBD). Tetrahydrocannabinol is the principal intoxicant cannabinoid in marijuana, CBD is the principal non-intoxicant cannabinoid considered to have great medical potential. Industrial hemp produces mainly CBD, while marijuana biotypes produce mainly THC. The relationship between THC and CBD is antagonistic; CBD reduces the intoxicant effects of THC.

The World Health Organization recently concluded that CBD is not associated with any abuse potential, but rather has a number of positive effects [8]. Cannabidiol has potential to be an effective treatment for cancer, Alzheimer's disease, Parkinson's disease, arthritis, inflammation, anxiety, diabetes, and other serious conditions [9, 10]. Since oilseed cultivars produce more flowers than fiber cultivars, they are a more promising source of CBD. It may be a feasible strategy to grow conventional oilseed cultivars for a dual crop, collecting both seeds and CBD, more research is needed. Potential economic value of CBD may exceed that of medical and recreational marijuana combined. The medicinal legal status of CBD in Canada and the USA has yet to be fully resolved.

Novel Uses for Hemp

Hemp Microgreens

"Microgreens" is a marketing term that refers to edible greens grown from seeds of vegetables and herbs, typically harvested when they are 7-14 days old. Flavor is more intense and they are considerably more nutrient-dense than mature greens. In age, microgreens are older than "sprouts" and younger than "baby greens", and only have a few days of shelf life. Microgreens can be used to garnish soups, salads and sandwiches.

Several individuals in the USA have attempted production of hemp microgreens to test the feasibility of this marketing option. Producers need viable hemp seed on hand continuously to plant every few days. Legal issues include the fact that commerce in viable hemp seeds is strictly controlled, and it is considered illegal to be transporting hemp plant parts from one location to another in the USA without strict security arrangements. From a practical standpoint, however, hemp microgreens do not contain a significant quantity of any cannabinoid.

Hemp Breeding

Industrial hemp has been selected for fiber traits for hundreds of years, with relatively modest gains anticipated in the near future, while selection for grain traits has only recently been pursued. For grain production, maximizing efficiency of production and ease of harvesting involves focusing on development of short, high harvest index plants [11]. This process could be facilitated by including the wide range in diversity currently existing in low stature marijuana *Cannabis*, but including marijuana germplasm in hemp breeding programs is currently not allowed.

Environmental Impact

Hemp is generally pest-tolerant, and has been successfully grown in Canada for 20 years without need for pesticides. However, widespread use of single plant selections and inbreeding have reduced genetic diversity and made many present-day cultivars more susceptible to pathogens and pests [12]. A significant white leaf spot disease has been found on hemp in several states in the USA after only a couple years of production. It is not yet clear if this is the same organism in different regions, or if it is the previously identified white leaf spot on hemp, *Phomopsis ganjae*. Compared to other annual row crops, hemp can have lower environmental impacts, particularly from a pesticide standpoint. But the fact remains that hemp is an annual row crop that requires relatively high fertilizer inputs and has a relatively high water requirement. Environmental benefits of hemp commonly found in the popular press tend to be exaggerated. On the other hand, hemp can be grown organically easier than most other row crops.

Economics

A number of economic analyses of a potential hemp industry in the USA have been conducted over the past 20 years [13]. Studies cited uncertainty about long-term demand and the potential for oversupply, which are typical concerns for the introduction of any new novel field crop. Lack of a viable processing industry also was cited. Previous studies were typically focused on hemp fiber and not on hempseed. Hemp fiber requires large, expensive and relatively dedicated processing facilities, while hempseed can utilize existing seed processing facilities with minor adjustments.

There are now hemp decortication plants operating in Manitoba, western Canada, and in North Carolina, USA. The North Carolina facility has an 18,000 tonne per year capacity and is processing both hemp and kenaf fiber. As with any biomass processing operation, there are two primary keys to economic success. One is the available resources to construct and operate a huge processing plant, and the other is to provide enough feedstock to keep the plant running year round. The second point is particularly challenging, as hemp fiber is bulky and is produced during one short period of the year, and needs to be stored indoors.

Politics

Approximately 300 industrial hemp bills have been proposed in state legislatures across the USA to-date. The extraordinary widespread, diverse political support for a novel field crop is unprecedented, and somewhat suspicious. Many legislators proposing hemp laws have no history of interest in field crops. Hemp legislation has been proposed in states with environments not suited for growing hemp. Much of the “support” for industrial hemp in the USA is really focused on paving the way for legalizing recreational marijuana. It is not clear how much support for hemp will remain if and when recreational marijuana is legalized federally. Few states have conducted any sort of feasibility study to evaluate hemp potential in their state.

The American Farm Bureau Federation is one of the largest and most active national farm organizations in the USA. In September, 2017, Farm Bureau presidents from 27 states signed a letter sent to the US Secretary of Agriculture requesting that industrial hemp be declassified as a Schedule 1 controlled substance, allowing USA farmers to engage in legal hemp production from a federal perspective. Although several bills have been proposed in the federal legislature regarding hemp, it is uncertain if and when industrial hemp will be declassified federally in the USA.

Conclusion

Industrial hemp has considerably more potential as an oilseed crop than as a fiber crop in North America at this time. The oilseed hemp industry is most in need of high-yielding cultivars to double the average productivity of oilseed hemp in North America, and make it economically competitive with other oilseed crops. High seed losses also need to be addressed with improved harvesting technology and breeding to minimize shattering losses through development of dwarf germplasm. Dietary advantages of hempseed and hempseed oil are quickly gaining acknowledgment. It is anticipated that the market for organically-produced hempseed will expand greatly, and relatively local production is usually required to meet organic certification standards. Many companies in North America are currently investing in CBD research, production, processing, and marketing.

Cannabidiol production has the potential to greatly surpass the combined fiber and oilseed markets, if regulatory agencies take a reasonable approach when addressing CBD.

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Wednesday, 28 February 2018

SESSION 2
Learning from other industries: The last 50 years in…

Chair: Lyn Stephenson, President, Industrial Hemp Association of Victoria

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Grapes, Wine and Hospitality
Lyndsay Sharp, Director of Marketing, Sales and Hospitality, Sharp Group (Jack Rabbit Vineyard, Leura Park Estate, Flying Brick Cider Co.)

The Australian Cotton Industry
Adam Kay, CEO, Cotton Australia

The Australian Olive Industry
Leandro Ravetti, Technical Director, Boundary Bend Olives

Grapes, Wine and Hospitality

Lyndsay Sharp,
Director of Marketing, Sales and Hospitality,
Leura Park Estate,
1400 Portarlington Road,
Curlewis, VIC 3222

lyndsay@leuraparkestate.com.au

Lyndsay Sharp is Director of Marketing, Sales and Hospitality, for the Sharp Group, which comprises Leura Park Estate, Jack Rabbit Vineyard and the Flying Brick Cider Company, all of which operate on the Bellarine Peninsula south of Geelong.

Lyndsay started her career in wine and food as the publicist for the then new Melbourne Food and Wine Festival in 1993. After more than 10 years in this and other PR roles, she and her husband, an accountant who came from a sheep farm in the Western Districts, bought the 60 ha Leura Park Estate in 2007. Leura Park now produces 5000 dozen bottles of wine, selling through their cellar door. The couple have since created Jack Rabbit Vineyard and the Flying Brick Cider Company.

Each business relies on excellent fruit and optimization of their manufacturing and cellar door assets.

The Australian Cotton Industry

Adam Kay,
CEO Cotton Australia,
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Mascot, NSW 2020

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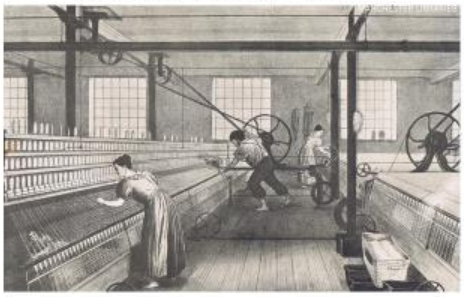
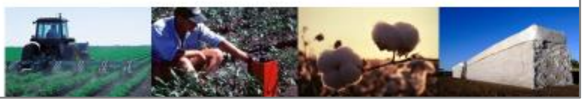
Cotton was a major catalyst & driver of the Industrial Revolution in the 1800's



England was hungry for raw cotton



COTTON AUSTRALIA

The Australian Industry emerged in Qld in 1850's

Early areas included:

- Emerald
- Theodore
- Capella
- Townsville
- Carrara
- Ipswich
- Beaudesert
- Thornton
- Laidley
- Rockhampton
- Wowan

COTTON AUSTRALIA

COTTON AUSTRALIA

Continued production in Qld into 1920's

History of Australian Cotton

This young lady, Miss Chown, was a champion picker of cotton. She could pick 85 lbs of cotton in eight hours.

1960's modern industry begins

COTTON AUSTRALIA

Industry Structure

COTTON AUSTRALIA

Establishment of key industry bodies in the 1960s and 70s

Cotton Seed Distributors (CSD)

- Established in 1967
- Growers realised that germplasm was critical
- Grower owned and controlled

ACGRA

- Australian Cotton Growers Research Association set up in 1972
- Aim to support R&D
- Focus research on grower needs
- Set up a 25 cent bale levy for R&D with 100% support

Australian Cotton Foundation

- Australian Cotton Foundation set up in 1972
- Public relations, industry image and government relations

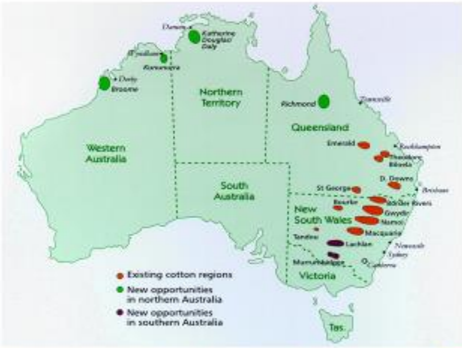
Australian Cotton Industry Council

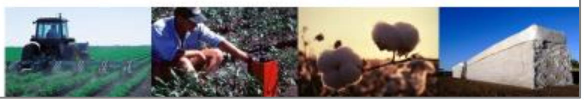
- Australian Cotton Industry Council was set up in 2001
- Membership of all industry organisations ie ginners, classers, consultants, seed companies, researchers etc
- Clearing house for industry issues

Today's Industry Bodies

- Australian Cotton Foundation and ACGRA merged to form Cotton Australia (still voluntary levy $1.25)
- Cotton R&D Corporation formed in 1990 (compulsory levy $2.25 bale matched by Government)
- Australian Cotton Industry Forum

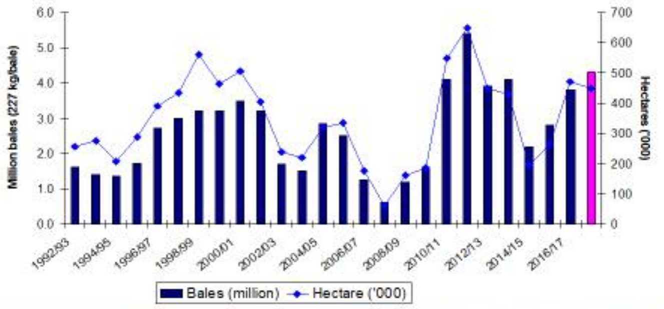
Location of the industry





COTTON AUSTRALIA

Australian Cotton Production and Area



COTTON AUSTRALIA

COTTON AUSTRALIA

Importance of Cotton Industry

COTTON AUSTRALIA

$2.5 billion dollars export income

COTTON AUSTRALIA

Employs over 10,000 people

COTTON AUSTRALIA

Clothing the world

(Australian cotton clothes 500 million people each year)

22

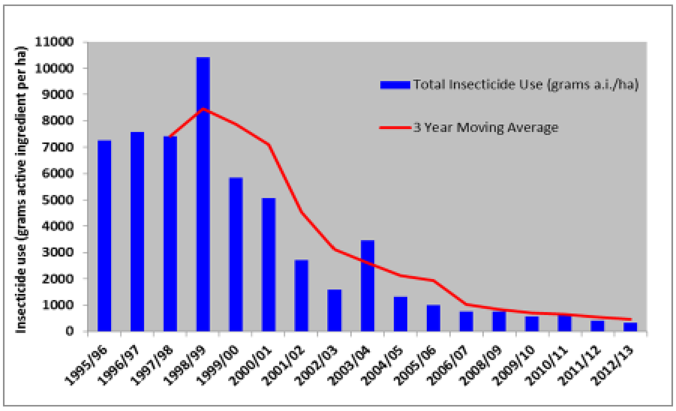
Importance of R&D

R&D Areas of Investment and Progress

- Soils
- Insects
- Weeds
- Yield
- Fibre Quality
- Water Use

23

Reduction in pesticide use over 90%



Weeds – now
(Herbicide tolerance biotech)

COTTON AUSTRALIA

The Water and Cotton Story

- Over 40% increase in WUE over last decade
- Australian growers produce "more crop per drop"
- Efficient users of water
- World's most water efficient cotton producers
- Cotton is "thrifty" not "thirsty"
- Best return per megalitre

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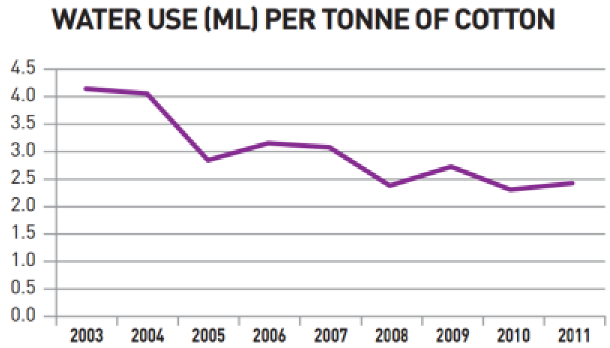
COTTON AUSTRALIA

Water Use Improvements



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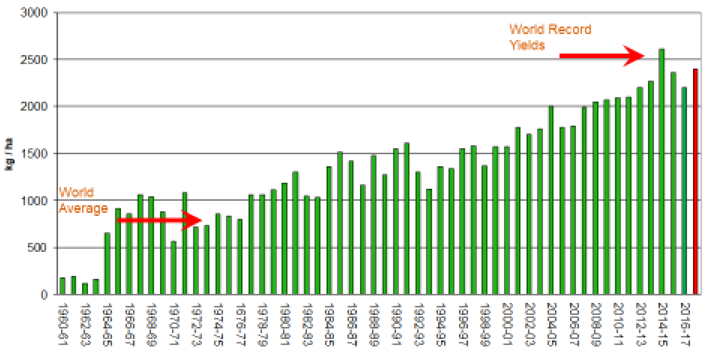
COTTON AUSTRALIA

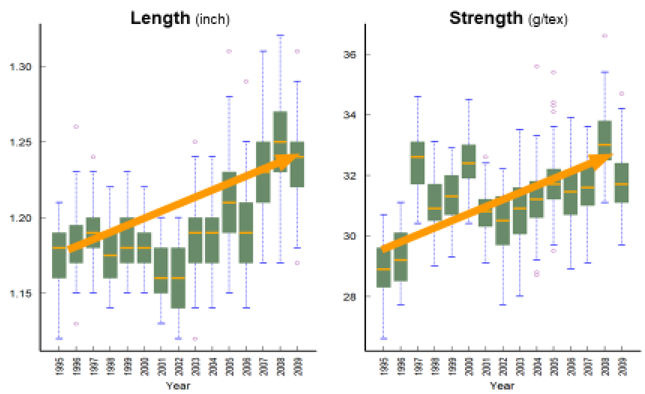
Cotton Variety Development

CSIRO Cotton Breeding Program,, Narrabri NSW

Yield record in Australia



Fibre Quality Improvements



High quality fibre in demand at spinning mills

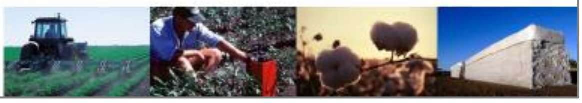
- Australian Cotton has a good reputation for spinning ability and producing high quality yarns
- Good length, strength, colour, low trash content and low (zero) contamination

Environmental Stewardship

- Minimal impact
- Environmentally responsible
- Growers are audited
- Overseas acceptance

BMP COTTON
BEST MANAGEMENT PRACTICES

COTTON AUSTRALIA



BETTER COTTON INITIATIVE (BCI)

BCI Better Cotton Initiative

- BCI is a not-for-profit organisation stewarding global standards for Better Cotton, bringing together cotton's complex supply chain, from the farmers to the retailers
- Partnership agreement signed in June 2014
- myBMP-certified cotton can be shipped as BCI Cotton (often attracting a premium)

COTTON AUSTRALIA

COTTON AUSTRALIA

BRAND & RETAILER MEMBERS OF BCI

INDITEX
LEVI STRAUSS & CO.
Walmart
vf
stadium
Hemtex
TESCO
adidas GROUP
George.
LINDEX
H&M
M&S
KappAhl
MQ
Jackpot
MIGROS
Sainsbury's
ginatricot
IKEA
BESTSELLER
Tchibo
AXSTORES

COTTON AUSTRALIA

Agriculture working together

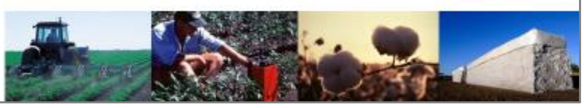
- Agricultural industries need to work together
- Negative comparisons to other agricultural industries are not useful and damages Australian agriculture
- In natural fibres we need to work together against the real competition

  Man made Fibres (MMF)

Summary

- History of industry
- Industry structure
- Growth and location of industry
- Importance of R&D
- Importance of cotton industry
- Global Recognition
- Agriculture working together

COTTON AUSTRALIA



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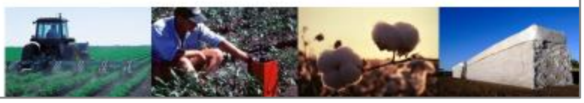

Learning from other industries: The last 50 years in the Australian Olive Industry

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Keywords: Olive oil, vertical integration, market, production

Overview of Australian Olive Industry

Olive growing history in Australia is quite recent with the first orchard established around Sydney in the early 1800's. By 1844, olives were introduced in South Australia near Adelaide and by 1890 Australia had the very first olive growing attempts along the Murray River in Victoria [1]. The evolution of the olive growing area was quite slow until the first half of the twentieth century when it jumped from a few hundred hectares to 1,500 hectares and reaching 3,000 hectares by 1960. Following the 1960 peak, olives remained a cottage industry with a declining area under cultivation until the resurgence of the industry towards the end of the century.

The olive oil industry began to gather momentum in the early 1990's, with several factors acting as catalysts for this growth: increasing popularity of Mediterranean food and growing market demand; a perceived opportunity to replace imported olive oil; a perceived opportunity to receive price premiums for Australian based on their quality and for the ability to supply fresh oil during the European summer; the establishment of large-scale investment plantations driven by the introduction of the Australian Tax Office Product Ruling system in 1998, which allowed investors to receive an upfront tax deduction for some or all of the initial and ongoing cost of their investment; and the establishment of large numbers of boutique or life-style groves.

Nationally, olive oil production has climbed from less than 1,000 tonnes in 2002 to 17,000 tonnes in 2011 [2]. It is estimated that 12,000 tonnes of this production have been consumed in Australia representing 30% of the total domestic market. The remaining 5,000 tonnes have been exported with the United States of America, European Union, China and several South East Asian countries as the main destinations. Nowadays, domestic olive oil production reached just over 20,000 tons.

When considering the new Australian olive industry, we have to think about a modern olive growing model pursuing maximum profit with sustainable production methods. In order to achieve this objective, it has been necessary to pursue high fruit and oil yields, the highest price for the final product and minimal production costs. Olive oils from Australia have quickly gained a reputation as a consistent high quality product. Best horticultural practices in combination with timely harvesting and purpose built processing facilities using state of the art technology are the main reasons that support the production of fresher and higher quality oils.

Industry statistics estimate that Australia has approximately 30,000 hectares of olive groves and more than 2,000 producers. Several surveys conducted since 2005 found that 90 percent of growers had less than 10 hectares while another nine percent had between 10 hectares and 100 hectares. The remaining one percent of Australian growers, with more than 100 ha, has been producing approximately 90 percent of the country's olive oil crop. The Australian olive oil industry is highly vertically integrated with most medium and large groves having their own processing plants and commercial brands. In Australia, there are approximately 100 olive mills at an estimated average of one mill for every 300 hectares. The vast majority of those mills utilise modern continuous two-phase extraction systems [3].

Australian growers are represented by the Australian Olive Association (AOA), which has been the national peak body for the Australian olive industry since 1995. The AOA has Board of Directors who is elected by their State Associations and the Large Enterprise Growers to discuss current issues and future strategies to ensure the industry's continued prosperity, growth and sustainability.

The AOA implements an ongoing consumer awareness programme (CAE) to promote the benefits of Australian extra virgin olive oil (EVOO) to consumers. Each October, the AOA holds the National Olive Industry Conference and Trade Exhibition which brings together national and international experts to discuss the latest in technology and research. The industry also gathers at this time to celebrate the season's success at their Gala Awards Presentation Dinner when the best oils and olives of the season are recognised.

The AOA is responsible for setting and maintaining quality standards for Australian products which is achieved by growers joining the Australian Olive Industry's Code of Practice (COP). The AOA Code of Practice guarantees the authenticity and quality of certified products and distinguishes them from imported and uncertified domestic products. To be certified, products must be Australian, have undergone strict organoleptic and chemical testing and comply with the Australian Standard for Olive Oils and Olive-Pomace Oils (AS 5264-2011).

Until July 2011, Australia did not have an existing Standard for olive oils or olive-pomace oils. Following a rigorous development process taking almost 8 years, involving multiple industry stakeholders and almost 800 public comments, Standards Australia approved a new olive oil standard (AS 5264-2011), bolstering consumer protection.

The objective of the Australian Standard was to establish a scientifically based and consumer-oriented standard for olive oils and pomace olive oils traded in Australia. While the Australian Standard and other international standards have a number of areas in common, particularly associated to worldwide recognized analytical methodologies and critical limits, AS 5264-2011 significantly differs in a number of aspects. Some of those points of difference include a simpler and clearer commercial denomination of the different categories of olive oils and olive pomace oils in order to avoid the current misleading and confusing terms such as extra light or pure. Additionally, a review and some modification of the range limits for a number of chemical parameters was undertaken in order to avoid genuine olive oil, particularly Australian, being excluded for its natural variation in composition. The introduction of recently developed analytical methods which are capable of detecting modern refining techniques not currently detectable by the older methodologies included in the above standards was also an integral part of the standard.

Australian Growing Regions
Olive oil in Australia is produced in almost every state, with more than 40 informally established olive growing regions, many of those mirroring some of the country's most recognised wine regions. Australia's olive oil regions are mainly in the southern, cooler parts of the country, with the vast majority of olive groves located in South Australia, New South Wales, Victoria and Western Australia. The main varieties cultivated include Arbequina, Barnea, Coratina, Corregiola, Frantoio, Hojiblanca, Koroneiki, Leccino, Manzanillo, Nevadillo Blanco, Pendolino, Picual, Picholine, and South Australian Verdale.

In order to simplify the analysis of Australia's growing areas, they have been grouped in four main regions: Northern, Central Northern, Central Southern and Southern Regions based on their distinctive climatic conditions, varieties performance and oil styles [4, 5, 6 & 7].

Conclusion

With an expected peak production by 2023 of approximately 30,000 tonnes of olive oil, the Australian olive industry volumes will continue being small in world terms. Nonetheless, the leading role of Australian orchards in grove modernisation and mechanisation, the uncompromising view of Australian producers on extra virgin olive oil quality and the public recognition of its Standard have revolutionised this traditional industry.

There is a generalised consensus that mechanisation of the most critical orchard practices is essential for the long-term sustainability of the global olive industry. Nonetheless, it is even more critical for the future success of the olive industry as well as for consumer satisfaction that the current international and domestic analytical methods and chemical limits for olive oil are reviewed. This review has to consider the natural variability of olive oils, the need to be able to readily identify and control new adulteration techniques and the inclusion of a measurement of the freshness of olive oil as an important parameter for oil classification.

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Wednesday, 28 February 2018

SESSION 3
Growing industrial hemp

Chair: Phil Warner, Founding Director, Ecofibre Australia

Industrial hemp on the Canadian Prairies
Jan Slaski, Team Leader Innotech, Alberta Canada

The Valley Bio-Experience – what has the last 10 years of growing industrial hemp told us?
Reuben Stone, President, Valley-Bio Limited, Ontario Canada

Industrial hemp in the USA (Kentucky)
David Williams, University of Kentucky, Kentucky USA

Breaking down Australian hemp farming
James Hood, Australian Primary Hemp, VIC

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ECOFIBRE
Industries Operations

Cultivation of industrial hemp on the Canadian Prairies for fibre, food and bioactive compounds

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Key words: industrial hemp, multipurpose crop, agronomy, Prairies, Canada.

Abstract

Currently the hemp industry in Canada is growing by 20-30% on an annual basis, with exports doubling in the last two years, approaching $150 million in 2016. By 2023, the Canadian hemp industry is expected to grow to $1 billion. In 2017, over 55,000 hectares (137,000 ac) were licenced for hemp production, with 33% of the area grown in Alberta – the largest among the Canadian Prairie provinces. This growth is driven by booming demand for grain and fibre raw materials for domestic and international markets including healthy food products, non-narcotic compounds and environmentally friendly fibre-based products such as biocomposites, sustainable building materials, textiles, super-absorbents and nanomaterials.

While Canada is the largest hemp food producer and exporter globally, Alberta is a North American leader with regards to development and production of hemp fibre cultivars, processing hemp feedstocks and manufacturing industrial goods incorporating different fractions of hemp fibre. InnoTech Alberta, a primary provincial applied R&D organization, is currently running the most comprehensive North American research program focused on industrial hemp. The “Seed to Final Product” program established at InnoTech Alberta over 16 years ago encompasses a research continuum of all aspects of this multipurpose crop.

This presentation will highlight research activities focused on the development of best management practices permitting sustainable production of hemp in different agro-ecozones of the Canadian Prairies. Particulars for selection of a suitable field, seeding practices including variety selection and effects of day length on grain and fibre production, major pest and diseases, crop management under rain-fed and irrigation conditions, nitrogen fertilization and other factors affecting crop performance will be discussed.

Cultivation of industrial hemp on the Canadian Prairies

Jan J. Slaski Ph.D., P.Ag. (Dist.)
Vegreville, Alberta, Canada

InnoTech ALBERTA

Geelong, February 28, 2018

The Canadian Prairies

Total area - 1,780,650 km²
Farm land – 135.5 M ac
SK - 64.3 M ac (38.5%)
AB - 52.1 M ac (31.2%)
MB - 19.1 M ac (11.4%)

InnoTech ALBERTA

Establishing hemp as a mainstream crop for industrial applications

To realize potential residing within industrial hemp 16 years ago InnoTech Alberta assembled a program offering solutions from "**Seed to final product**" composed of three R&D domains

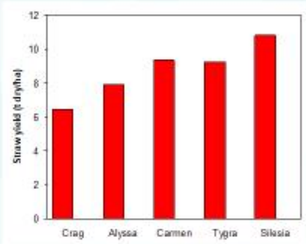
Feedstock development research goals

To **secure supply** of fibre of uniform quality and quantity and to **reduce costs** of fibre production



Hemp selection and breeding

- Germplasm evaluation
- Selection of top performers under AB conditions
- Maintenance breeding of cv. Silesia
- Initiation of new cultivars breeding for Alberta



Hemp usage types and breeding objectives in Canada

Grain type
- Short stature
- High seed yield
- Low vegetative biomass

Fibre (dual) type
- Tall or very tall plants
- Very high stem yield
- Lower seed yields

InnoTech ALBERTA

InnoTech Alberta agronomy trials

Objective:

Optimization of cultivation practices on the Prairies

- Seeding densities (100 and 250/300 seed/m^2)
- Seeding dates (mid May - mid June)
- Fertilizers (cattle manure, mineral)
- N rates and forms (ammonia, urea)
- Harvest dates (for juvenile fibre)
- Herbicide resistance

Completed four year trials at three locations across Alberta

InnoTech ALBERTA

Study sites in Alberta

1. Falher – north
2. Vegreville – central
3. Lethbridge – south (**irrigated**)

Location	Lethbridge	Vegreville	Falher
Precipitation (mm)	252	297	323
Ave temp (May-Aug)	15.7	14.3	13.8
Soil type	Dark Brown	Black	Dark Gray
Day light on June 21	16 h 19 min	17 h 2 min	17 h 33 min

Field selection

- Hemp is very sensitive to soil structure
- Yield penalty on compacted soils
- Does not tolerate soils with poor drainage

InnoTech ALBERTA

Seeding

- Seed shallow - ~ 1.5cm (or into moisture)
- 20-25 kg/ha seeding rate for grain
- 40-60 kg/ha for fibre
- Warm soils – above 8°C
- High field mortality (10-70%)
  add 30% when calculating seeding rates
- Equipment – low fan speed for air seeders

InnoTech ALBERTA

High fan speed damages the seeds

InnoTech ALBERTA

Seeding date

- Affects more yield of crop grown for fibre, less critical for grain
- Hemp is a short day plant
  - Long days (over 17 h) at higher latitudes delay flowering
  - Stem elongation occurs before flowering
  - Early seeding generates taller plants and more vegetative growth

InnoTech ALBERTA

Effects of seeding date on hemp performance (Lethbridge)

Seeding date	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest Index	Height (cm)	Male plants (%)	Flower (DAS)	Maturity (DAS)
Early	1884	**5379**	0.28	**181.2**	32.6	47.8	102.3
Standard	1828	**4811**	0.32	**176.0**	36.0	38.6	88.0
Late	1581	**4277**	0.30	**166.6**	37.8	34.7	78.8

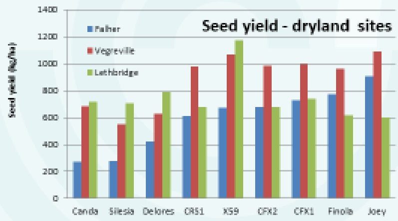
Delayed seeding – shorter plants, while grain yield not much affected (extremes mid-June to July 16)

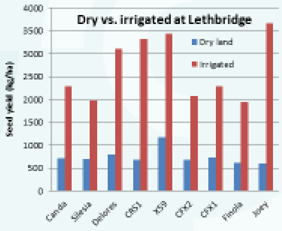
InnoTech ALBERTA

Cultivar selection – attainable seed yields

Yield range in commercial conventional dryland production:

- Grain - 50-1500 kg/ha
- Fibre - 500-10000 kg/ha

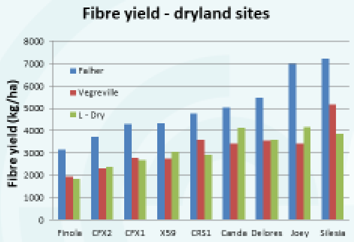


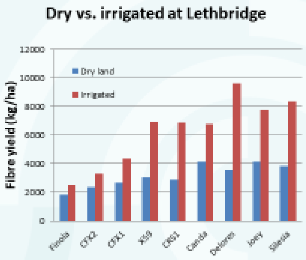


InnoTech ALBERTA

Irrigation substantially increases grain yield

Cultivar selection - fibre yields





- High fibre yields in the northern portion of the province
- Irrigation increases fibre yield of dual purpose cultivars

Weather factors may dramatically impact fibre (and grain) yields

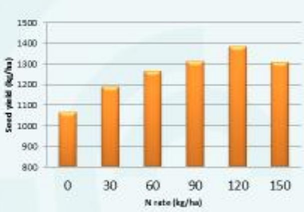
InnoTech ALBERTA

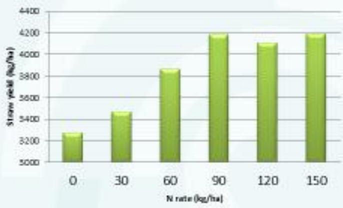
Fertilization

- Rule of thumb for fertility recommendations
  - a high yielding and high protein spring wheat
- Hemp is sensitive to N fertilizer placement
  – side-banded, mid-row-banded or banded in a separate operation

InnoTech ALBERTA

Hemp response to nitrogen fertilizer



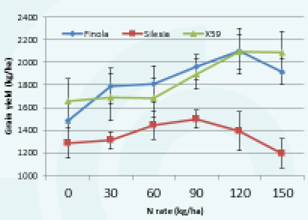


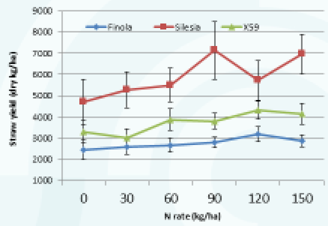
Grain yields:
- Maximum yields at 120 N kg/ha
- Grain yield reduction at higher yields (N toxicity ?)

Fibre yields:
- Maximum yields at 90 N kg/ha
- No benefits of luxury fertilizer

InnoTech ALBERTA

Differences among hemp varieties in N fertilizer response





Grain yields:
- Grain-type varieties - maximum yields at 120 N kg/ha
- Fibre type variety - maximum at 90 N kg/ha then decrease

Fibre yields:
- Grain-type varieties - weak response to increasing N rates
- Fibre type variety - maximum at 90 N kg/ha then plateau

InnoTech ALBERTA

Weed control

- Limited selection of herbicides registered for use on industrial hemp in Canada
  - Pre-seed burn-off with glyphosate
  - Grassy weeds - Assure II (Quizalofop-p-ethyl) from DuPont
  - Broadleaf weeds – Bromoxynil products (in registration)
- Cultural practices
  - Hemp is very competitive – closes canopy quickly
  - Pre-seed tillage accelerates establishment – does not like hard pan


InnoTech ALBERTA

Pests and diseases

- Sclerotinia - avoid rotation with canola
- Botrytis (grey mold)

Insects – rarely a real problem

- Bertha armyworm
- European corn borer
- Cutworms

InnoTech ALBERTA

Potentially causing economic crop losses: Cutworms (*Agrotis spp.)*

June 29, 2016,
Viking, Alberta

InnoTech ALBERTA

First major pest insect outbreak having economic consequences

- Following mild winter cutworms annihilated 70 acres of organic hemp.

- Good news: hemp was re-seeded on July 6 and grain harvested in October

InnoTech ALBERTA

Spring frost

- Hemp is fairly resistant to spring frost

-4.7°C on May 30

InnoTech ALBERTA

Hail injuries

- Extent of damage depends on:
  - plant stage
  - usage type
- Symptoms - leaf shredding, stem bruising, kinking and/or breaking of stalks, loss of flower heads

InnoTech ALBERTA

Recovery from hail injury

Hemp – a crop like no other

- Framers know how to grow staple Prairie crops (wheat, canola, barley, pulses)
- Hemp is different - you have to know what are you growing for and adapt cultivation practices accordingly

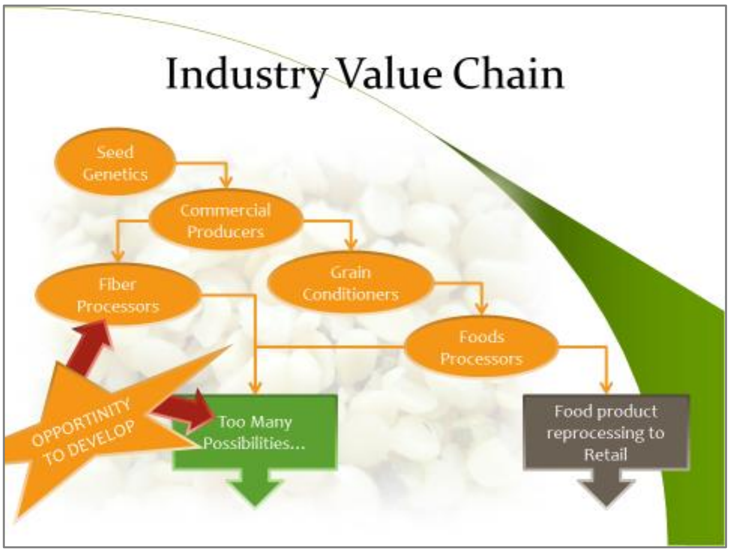

CHTA ACCC
Canadian Hemp Trade Alliance
Alliance Commerciale Canadienne du Chanvre
2018
PACIFIC RIM
HEMP CONFERENCE
July 18 - 19, 2018
Vancouver, BC, Canada
Thank you and see you in Vancouver

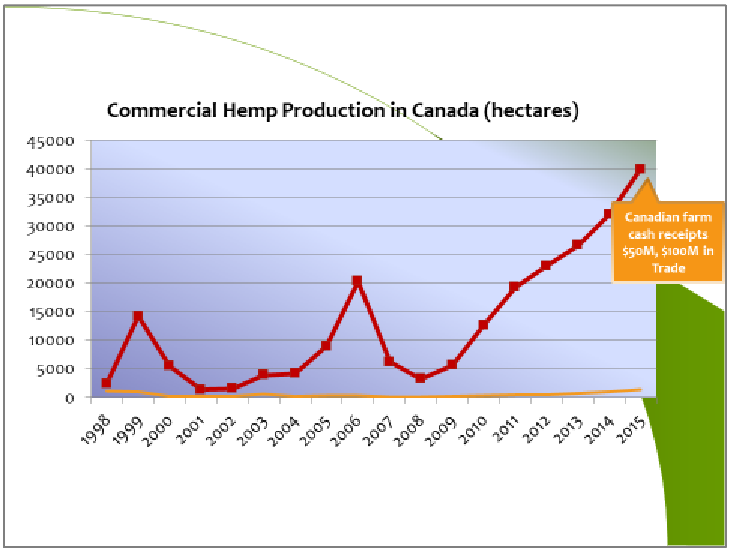
The Valley Bio-Experience – what has the last 10 years of growing industrial hemp told us?

Reuben Stone,
President, Valley-Bio Limited,
Ontario Canada

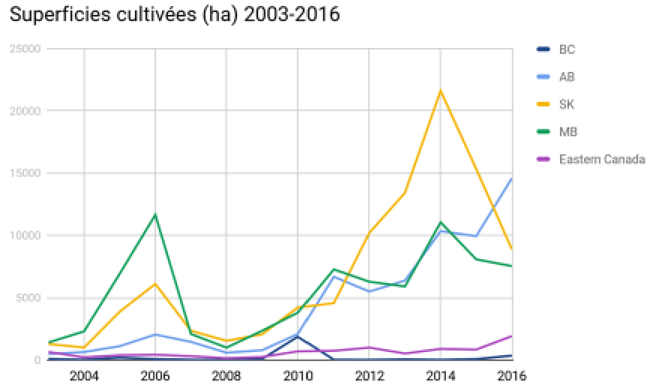
reuben@uniseeds.ca@stoneagri


STONE FARMS
SINCE 1901
ValleyBio
UniSeeds
• 1100 acres crop
• Pedigree seed since 2010
• Family Operation
• Cleaning grain in 2012
• Registered Seed Establishment in 2014
• 6 Employees
• Hemp Breeding program since 2012
• Registered Varieties:
• Anka, Carmen, Altair new 2018, Rigel new 2019
• Four New Varieties
SeCan

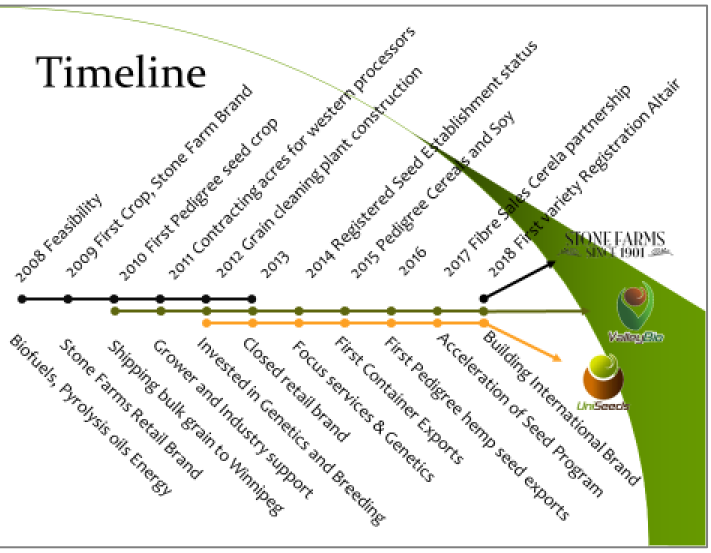

Industry Value Chain
Seed Genetics
Commercial Producers
Fiber Processors
Grain Conditioners
Foods Processors
OPPORTINITY TO DEVELOP
Too Many Possibilities…
Food product reprocessing to Retail

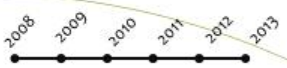

Commercial Hemp Production in Canada (hectares)
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Canadian farm cash receipts $50M, $100M in Trade

Canadian Hemp Cultivation



Timeline





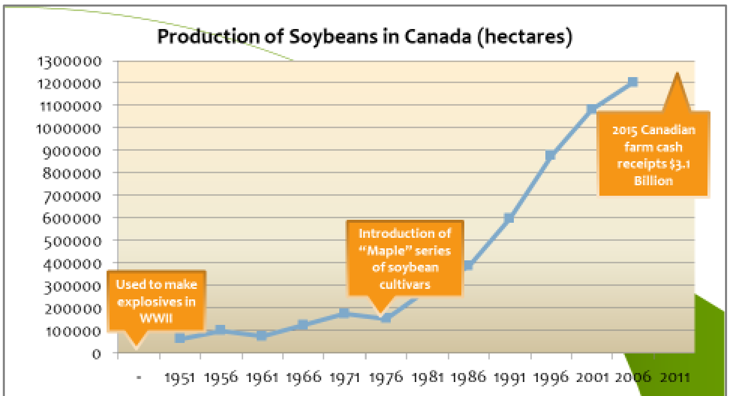
STONE FARMS
SINCE 1901

Advantages

- Higher overall margins, large piece of value chain
- Direct Farm to Field Marketing

Disadvantages

- Complexities of food grade processing
- Hard work for smaller sales
- Larger supply chain to manage
- Competition with other brands



- Modern Hemp is following a similar path to Soybeans of the 1960's… on a tighter timeline
  → In 1966 there were seven registered soybean varieties in trials in Ontario, there are now over 200!

Regulatory Environments

Health Canada

CFIA·ACIA

Canadian Grain Commission

- Controlled Substances Act
  - Review of the Industrial Hemp Framework (in progress)
  - Ease of access for growers
- Industry Oversight
  - Seed purity to food safety
- Canadian Grain Commission
  - Industry Standards

Genetics & Agronomy

Hemp missed out on the "green revolution"

CSGA Canadian Seed Growers' Association – High quality pedigreed seed; modernized varieties for mechanized agriculture

- Agronomic support: fertility, pest control, rotational benefit
- Public research
  - Reliable data makes confident growers!

Variables

- Varieties
- Seeding Dates, Seeding Rates
- Fertility Optimization
- Crop Protection Products

Metrics

- Grain and Straw Yield
- Grain Characterization
- Disease susceptibility
- THC/CBD concentration

Crop Science to Production

- Academic Extension
- Business Incubators
- Technology accelerators

  - More MONEY

- Soy Corn continue to benefit from Billions in investments
- Regional hemp schemes are getting political buy-in

Harvest Time – Market Time

- Is there a grain Surplus in Canada, Globally?
- Canada: too big to be small and too small to be big
- Need to open new grain market opportunities
- The fibre industry needs to catch up to grain

Market Acceptance

Industrial hemp in the USA (Kentucky)

David Williams,
University of Kentucky,
Kentucky USA

david.williams@uky.edu

Abstract
Production of industrial hemp (*Cannabis sativa* L.) continues to increase in the USA as additional states enact legislation supporting pilot research programs created by the 2014 federal farm bill. Acreages under production among states vary significantly, as well as regulations for participating in state-level pilot research programs. Additionally, accurate reporting (data) from states varies as well. Differences in legal regulations among states create problems for collaborative efforts and severely complicate commerce across state lines. For example, cannabinoids may be wholly illegal in some states to the same level as heroin, whereas cannabinoids may be fully legal in other states. Kentucky has led the nation in agronomic industrial hemp research since 2014. While other states have reported significantly more acreage under production, no other state has conducted science-based research on the same scale.

Research efforts are expanding significantly across the USA in 2018. In 2017, hemp production in Kentucky essentially met the demand created by existing processing capacity/infrastructure. This was true considering all of the harvestable components; fiber, grain and cannabinoids. Significant increases in processing capacity are expected in 2018 for fiber and cannabinoids, and production is expected to increase accordingly. Current industrial hemp research at the University of Kentucky (UK) include efforts in very diverse disciplines; agronomy, molecular biology, plant pathology, plant physiology, agricultural engineering, agricultural economics, and pharmaceutical sciences.

Agronomic efforts are aimed at defining efficient production models that optimize yields and profitability of all harvestable components. Examples include standard variety trials, establishment date, seeding rate, row spacing, herbicide efficacy/tolerance, and fertility trials.

Additionally, investigations of production models from other crops (e.g., tomatoes vs. tobacco vs. traditional grains) are being conducted with hemp. These production models vary greatly in inputs and are evaluated against potential profitability of the harvestable component. Today, cannabinoids have the highest profit potential. Fiber and grain are profit-competitive with the standard corn-soybean-wheat rotation common on grain farms in the central/eastern USA. Best management practices have not yet been elucidated for cannabinoids, but much progress has been made for fiber and grain systems.

Industrial Hemp in the USA (Kentucky)

D.W. Williams, Agronomist
University of Kentucky
Department of Plant and Soil Sciences

UK UNIVERSITY OF KENTUCKY College of Agriculture, Food and Environment

Credit: votehemp.com

Many differences among states…

- Kentucky and others: entire program is administered by the state department of agriculture. Universities are program participants much like farmers.
- Indiana and Virginia: entire program is administered by universities. This means universities are ultimately responsible to the federal government for compliance to federal and local laws (e.g., DEA, local law enforcement).

Many differences among states...

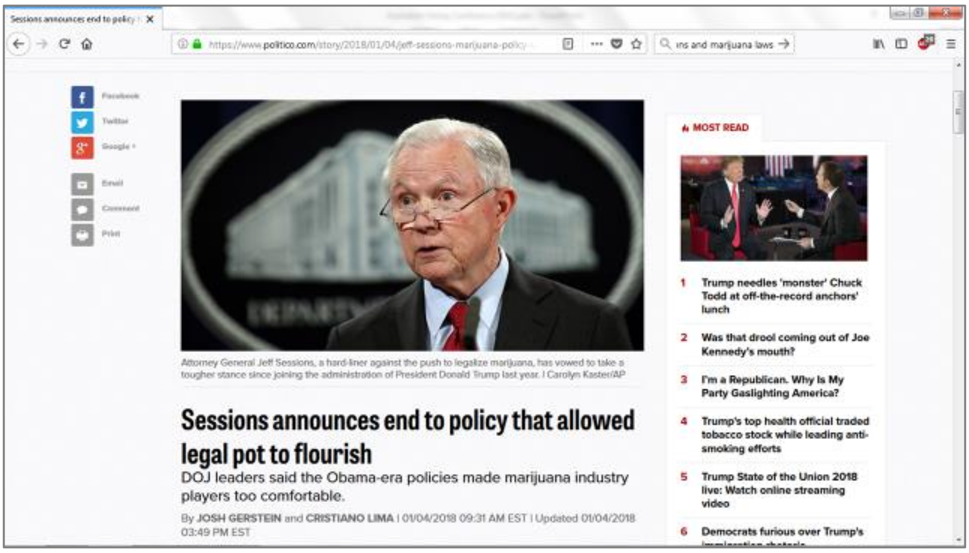
- Vermont: THC testing only by request of law enforcement; production is not regulated by the state at any level, so no reliable data on production.

- Kentucky and others: 100% of crop is sampled for testing. 100% of production is registered with the state department of agriculture through statutory licensure and reporting requirements. Otherwise, its wholly illegal.

Many differences among states...

- Indiana: all cannabinoids are wholly illegal; as per federal CSA all cannabinoids are schedule 1 controlled substances.

- Kentucky: cannabidiol (CBD) is a legal commodity as per state statute.



Many differences among states…

- Interstate commerce with processed fiber and processed grain for food (seed that cannot produce a plant or other foods from seed) does occur.

- By federal law, interstate commerce with cannabinoids would be wholly illegal, just as commerce with any form of marijuana is.

- There are still issues in the USA regarding banking and Cannabis businesses.

2017 Kentucky Industrial Hemp Research Pilot Program

WWW.KYAGR.COM/HEMP

Credit: Mrs. Doris Hamilton, KDA Industrial Hemp Program Manager

KDA Industrial Hemp Research Pilot Program

Annual Overview

Production Year	# University Projects	Approved Processors	Approved Growers	KY Counties with Hemp	Approved Acres	Planted Acres	Harvested Acres	% Grain/Seeds	% Fiber	% CBD	% CBD & Grain
2014	7	9	20	14	-	33	-	47%	32%	21%	
2015	8	29	99	41	1,742	922	500	47%	6%	47%	
2016	17	45	137	60	4,600	2,300	2,000	34%	6%	60%	
2017	17	49	204	71	12,800	3,200	2,300	36%	5%	27%	32%
2018 (Jan)	TBD	55	225	TBD	12,018						

Credit: Mrs. Doris Hamilton, KDA Industrial Hemp Program Manager

2017 Averages in Kentucky

- Grain-only: 500 lb/A {560 kg/Ha} ($0.70/lb)
  - Certified Seed?
- Floral material: 750 lb/A {840 kg/Ha} ($10.00/lb)
- Fiber-only: 1 ton/A {2.24 T/Ha} ($0.07/lb)
  - Economics? Dual-purpose? Kenaf (*Hibiscus cannabinus*)?

KENTUCKY CERTIFIED SEED

SS502594

THIS CERTIFICATION TAG IS ISSUED BY THE KENTUCKY SEED IMPROVEMENT ASSOCIATION FOR USE ON KENTUCKY CERTIFIED SEED PRODUCED IN ACCORDANCE WITH THE STANDARDS, RULES AND REGULATIONS ESTABLISHED UNDER AUTHORITY OF THE KENTUCKY SEED LAW.

NOTICE TO BUYER - LIMITATION OF WARRANTY

"THE SEEDS CONTAINED HEREIN ARE WARRANTED TO CONFORM TO THE LABEL DESCRIPTION WITHIN RECOGNIZED TOLERANCES AS REQUIRED UNDER STATE AND FEDERAL SEED LAWS. NO WARRANTIES ARE MADE, EITHER EXPRESSED OR IMPLIED, INCLUDING MERCHANTABILITY, FITNESS FOR PURPOSE OR OTHERWISE WHICH WOULD EXTEND BEYOND SUCH DESCRIPTION. IN ANY EVENT, LIABILITY FOR BREACH OF ANY WARRANTY OR CONTRACT OR FOR NEGLIGENCE WITH RESPECT TO SUCH SEEDS IS LIMITED TO THE PURCHASE PRICE OF SUCH SEEDS. AS A CONDITION TO ANY LIABILITY, NOTICE MUST BE RECEIVED BY REGISTERED MAIL OF ANY CLAIM THAT THE SEED IS DEFECTIVE WITHIN 30 DAYS AFTER THE DEFECT ON THE SEED BECOMES APPARENT."

KIND	INDUSTRIAL HEMP	PURE SEED	99.98%	GERMINATION	80.00%
VARIETY	TYGRA	CROP SEED	0.00%	HARD SEED	0.00%
LOT NO.	162-708201711C	WEED SEED	0.00%	NOXIOUS WEED	NONE
ORIGIN	KY	INERT MATTER	0.02%	NET WT. LBS.	40 LBS. / 18.14 Kg
		SEED COUNT	32,760 / LB	DATE TESTED	10/17

SCHIAVI SEEDS, LLC
LEXINGTON, KY 40504

SEED PRODUCED FROM FIELD THAT COMPLIES WITH THE DELTA-9 THC REQUIREMENTS, NOT TO EXCEED 0.3% AS OUTLINED IN 7 U.S.C. 5940 AND KY REVISED STATUE 260.850

MEMBER ASSOCIATION OF OFFICIAL SEED CERTIFYING AGENCIES

2017 Averages in Kentucky

- Grain-only: 500 lb/A {560 kg/Ha} ($0.70/lb)
  - Certified Seed?
- Floral material: 750 lb/A {840 kg/Ha} ($10.00/lb)
- Fiber-only: 1 ton/A {2.24 T/Ha} ($0.07/lb)
  - Economics? Dual-purpose? Kenaf (*Hibiscus cannabinus*)?

Sunstrand LLC

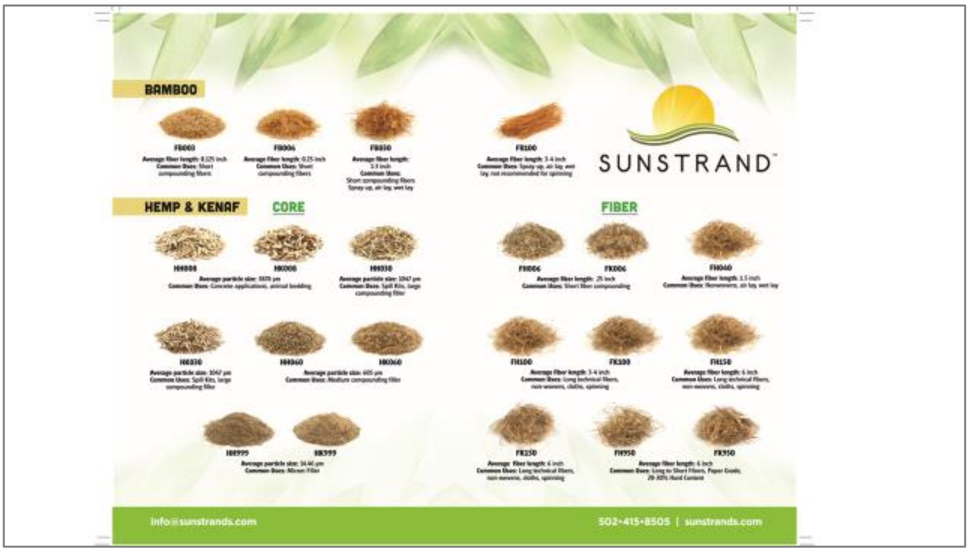
Main Fiber Line Area

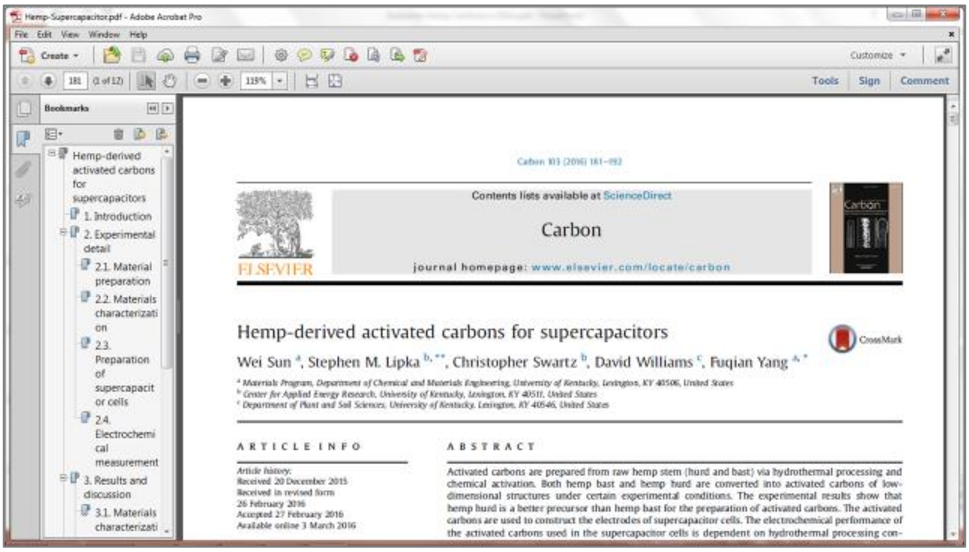
Dry (Mil) Processing

Wet (Reactor) Processing

Drying Line

Packaging


BAMBOO
SUNSTRAND
HEMP & KENAF
CORE
FIBER
info@sunstrands.com
502-415-8505 | sunstrands.com


Carbon 103 (2016) 181–192
Contents lists available at ScienceDirect
Carbon
journal homepage: www.elsevier.com/locate/carbon

Hemp-derived activated carbons for supercapacitors

Wei Sun [a], Stephen M. Lipka [b,**], Christopher Swartz [b], David Williams [c], Fuqian Yang [a,*]
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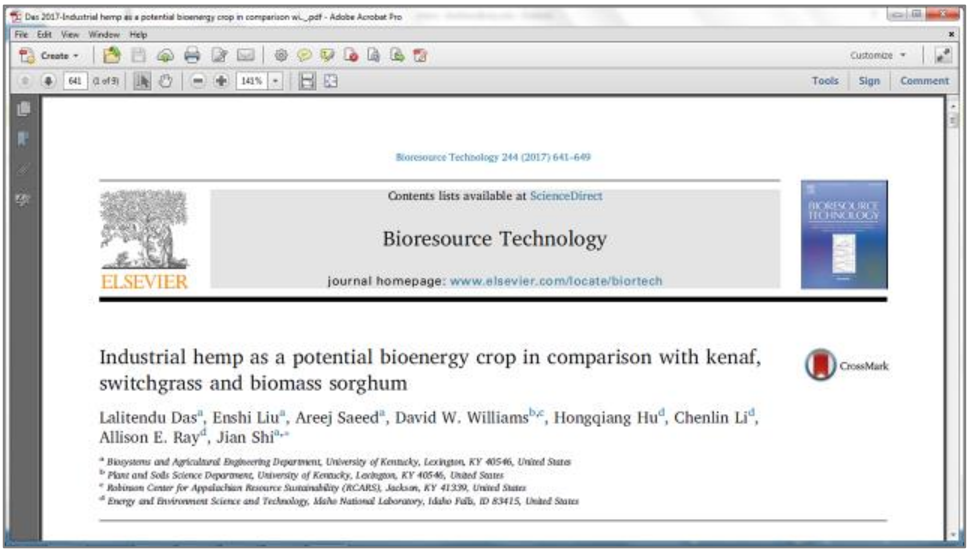
ABSTRACT

Activated carbons are prepared from raw hemp stem (hurd and bast) via hydrothermal processing and chemical activation. Both hemp bast and hemp hurd are converted into activated carbons of low-dimensional structures under certain experimental conditions. The experimental results show that hemp hurd is a better precursor than hemp bast for the preparation of activated carbons. The activated carbons are used to construct the electrodes of supercapacitor cells. The electrochemical performance of the activated carbons used in the supercapacitor cells is dependent on hydrothermal processing con-


Bioresource Technology 244 (2017) 641–649
Contents lists available at ScienceDirect
Bioresource Technology
journal homepage: www.elsevier.com/locate/biortech

Industrial hemp as a potential bioenergy crop in comparison with kenaf, switchgrass and biomass sorghum

Lalitendu Das [a], Enshi Liu [a], Areej Saeed [a], David W. Williams [b,c], Hongqiang Hu [d], Chenlin Li [d], Allison E. Ray [d], Jian Shi [a,*]
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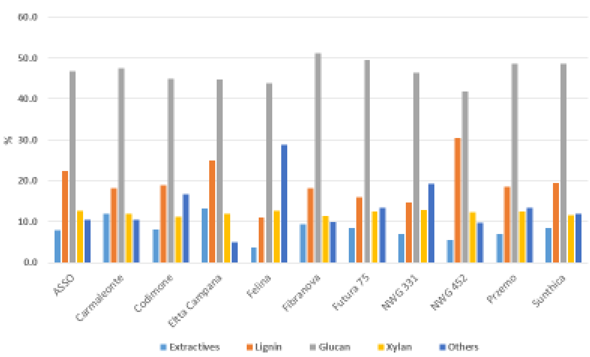
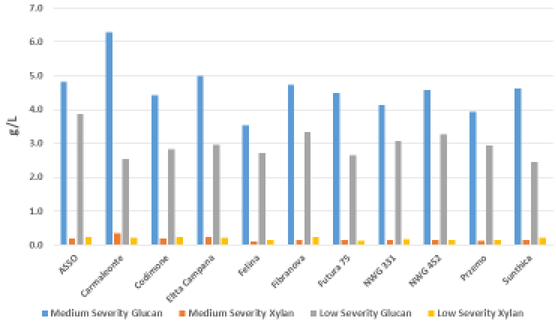
[b] Plant and Soils Science Department, University of Kentucky, Lexington, KY 40546, United States
[c] Robinson Center for Appalachian Resource Sustainability (RCARS), Jackson, KY 41339, United States
[d] Energy and Environment Science and Technology, Idaho National Laboratory, Idaho Falls, ID 83415, United States

Composition of stems from 11 hemp varieties



- Lignin contents varied largely from 11-30%, with *Felina* the lowest and NWG452 the highest among the eleven tested varieties
- All hemp varieties had high glucan contents in a range of 44-51%
- Xylan contents spanned a narrow range of 11-13%
- Overall, the composition data suggest that all hemp varieties have great potential for biofuel/chemical production in terms of fermentable sugars.

Preliminary sugar yield from enzymatic hydrolysis of dilute acid pretreated hemp varieties



Combined Severity: 2.1 (160 °C, 1% H_2SO_4)   Combined Severity: 1.8 (160 °C, 1% H_2SO_4)
Enzymatic hydrolysis: 10 mg/g enzyme loading of C Tec 2 + H Tec2 for 48 h

- Large variations in glucose yield were observed among the eleven tested varieties at both medium and low pretreatment severities
- We also noted large discrepancies in glucose yields at different pretreatment conditions, indicating the hemp varieties responded differently to pretreatment severities
- Very low xylose yields for all tested varieties suggest that most of the xylan has been removed during dilute acid pretreatment
- We are testing the impact of high severity pretreatment conditions

Types of Herbicides

Pre-plant/emergence – may provide residual control of germinating weeds

Product	Active ingredient	Product rate
Command 3ME	Clomazone	2/3 pt/A
Intrro 4EC	Alachlor	2 qt/A
Treflan 4EC	Trifluralin	2 pt/A
Spartan 4F	Sulfentrazone	12 oz/A
Sharpen	Safluenacil	1 oz/A
Prowl	Pendimethalin	3 pt/A
2,4-D B 200	2,4 D butyric acid	0.9 pt/A

Post-emergence – often selective providing control for specific types of weeds

Product	Active ingredient	Product rate
Buctril 2EC	Bromoxynil	0.75 pt/A
Basagran 4 E	Bentazon	1.2 pt/A
2,4 D B 200	2,4 D butyric acid	0.9 pt/A
Assure II 0.88 EC	Quizalofop-P-Ethyl	0.7 L/A

Credit: Dr. Bob Pearce and Ms. Sara Carter; UK agronomy research

Preliminary Observations

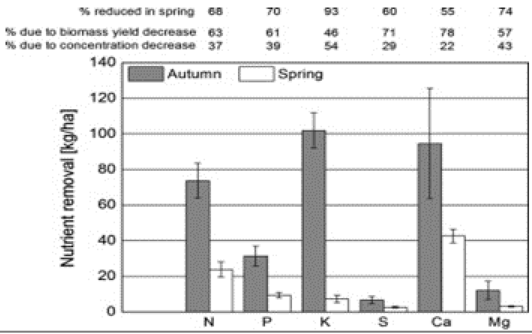
- Wide plant spacing in transplanted hemp crops may lead to more intense weed competition.
- Industrial hemp has shown tolerance to a range of currently available active ingredients used to control weeds in other cropping systems.
- In general transplanted hemp was more tolerant than direct seeded (more potential options available).
- Additional work is needed to identify potential targets to pursue for labelling. NO CURRENTLY LABELLED HERBICIDES
  - Efficacy testing
  - Crop tolerance under differing conditions
  - Establishment of residue tolerance

Credit: Dr. Bob Pearce and Ms. Sara Carter; UK agronomy research

Effect of harvest date on combustion related fuel properties of industrial hemp (*Cannabis sativa* L.)

Thomas Prade, Michael Finell, Sven-Erik Svensson, and Jan Erik Mattsson

Fuel. Volume 102, December 2012, Pages 592-604



University of Kentucky

College of Agriculture, Food and Environment

Agronomic Industrial Hemp Research

david.williams@uky.edu

http://hemp.ca.uky.edu

Breaking down Australian hemp farming

James Hood,
Director Australian Primary Hemp,
Derrinallum, VIC 3325

info@ausprimaryhemp.com.au

2017

Background

First Year of Business

2017

Farming Opportunities

Climate Conditions

6

australian primary hemp

Farming Opportunities

Soil Conditions

7

australian primary hemp

Farming Opportunities

Easily integrated

8

australian primary hemp

Barriers To Entry

We have identified three main barriers to entry.

1. Research and Development
2. Legal Parameters - DEPI
3. Knowledge and Education

www.ausprimaryhemp.com.au

9

Learning From The Best

australian primary hemp

Global Market Research

- Global demand (70% more food needed by 2050).
- Plant based proteins are a $13billion industry globally
- 2015 Global protein ingredients market size ca. US $24B
- 57% consuming more plant-based protein products (2016 vs. 2015)
- Plant-based protein to account for 1/3 world's protein market by 2050

Kelley Fitzpatrick, M.Sc. NutriScience Solutions, Protein Industries Canada

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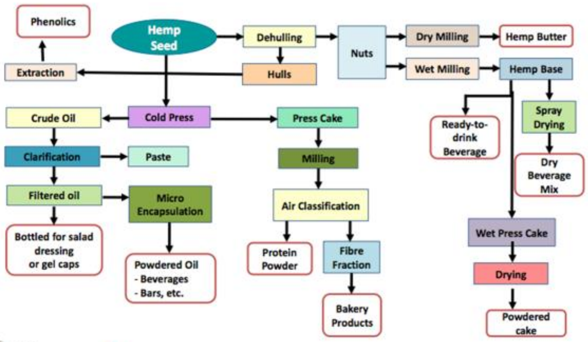
11

Hemp Seed Processing

australian primary hemp



Food Development Centre Growing Opportunities in Food

Hemp Seed Varieties

australian primary hemp

FINOLA

- The FINOLA variety of industrial hemp is a short, rapidly maturing, dioecious, auto-flowering oilseed crop that was developed in Finland for hempseed grain production.
- The grain can be harvested with a modern combine.
- FINOLA is cultivated like other industrial oilseed crops, such as rapeseed.
- Potential grain yields can vary; up to 1000 kg/ha in maritime climates near latitude 60° N and 2000 kg/ha in continental climates near 50° N. When soil, moisture and fertilization are optimal, grain yields are primarily dependent on the amount of thermal energy during the growing season.

www.ausprimaryhemp.com.au

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Hemp Crop Cycle

Hemp Crop Cycle

Hemp Crop Cycle

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Wednesday, 28 February 2018

SESSION 4
Hemp varieties for Australia

Chair: Jeff Kostuik, Chief Operating Officer, Hemp Genetics International, Canada

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Quality control: A key driver for consumer confidence and international reputation
Abdul Rehman Mohammed, Australian Cannabis Laboratories, VIC

Industrial hemp cultivar evaluation – trials vs commercial experience Down Under
Jo Townshend, Midlands, New Zealand

Commercial breeding and selection of low THC *Cannabis sativa* for sub-tropical environments
Omid Ansari, Ecofibre Australia, QLD

Industrial hemp production trials in Tasmania
Mark Boersma, University of Tasmania, TAS

Industrial hemp production trials in South Australia
Mark Skewes, SARDI, SA

The Australian dual purpose low thc variety *Frog One* – Performance in temperate and subtropical zones and research in tropical environments
Klara Marosszeky, Lismore, NSW

Quality control: A key driver for consumer confidence and international reputation

Abdul Rehman Mohammed,
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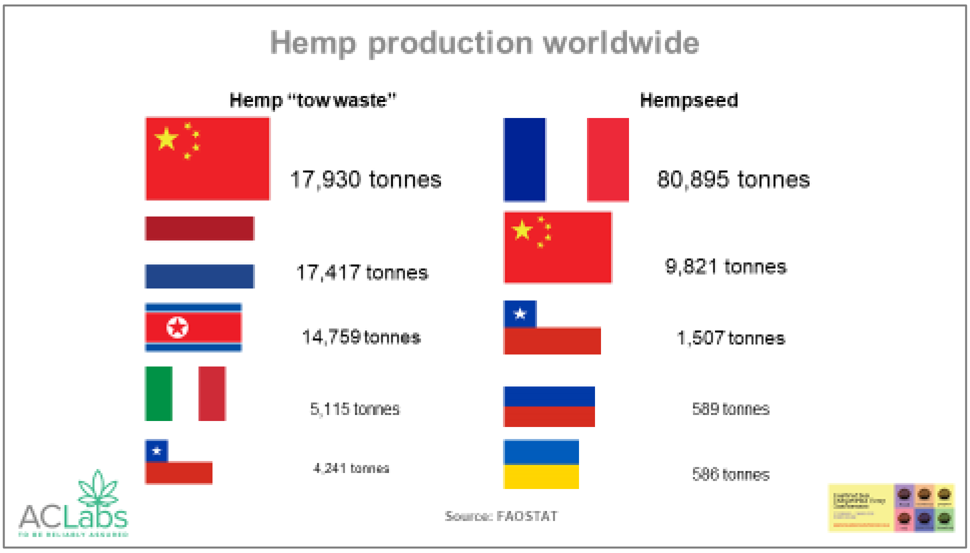

Australian production?

Comparison and challenges

- 185.5 hectares of industrial hemp were planted in Australia in 2011, producing around 93 tonnes of hemp seed. (AgriFutures data, 2011)
- This has estimated to have increased 6-8 fold till date, but still well short of major producers such as China, France and Chile.
- Australia also has the highest cost of production in agriculture as compared to its competitors (Rabobank report)
- Even at an increasing scale of production how will Australian hemp products compete in the global marketplace, if they are priced out???

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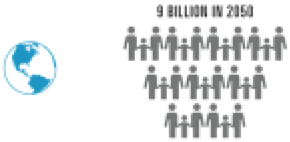
'Clean and green' is gold

-title credit Food Miles magazine



The Second Green Revolution is required to lift food production by 75%

Australia has a significant role to play in global food supply

In order to remain **internationally competitive**, Australia has to continue being modern, safe, reliable and sustainable producer of food

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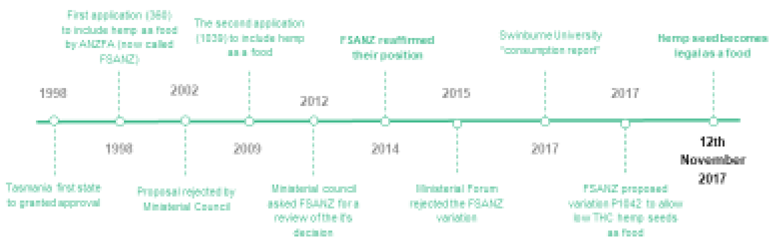
Hemp seed as food legislation

The timeline of events



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The laboratory
it's role in the industry
Compliance
Assurance
Verification
R&D
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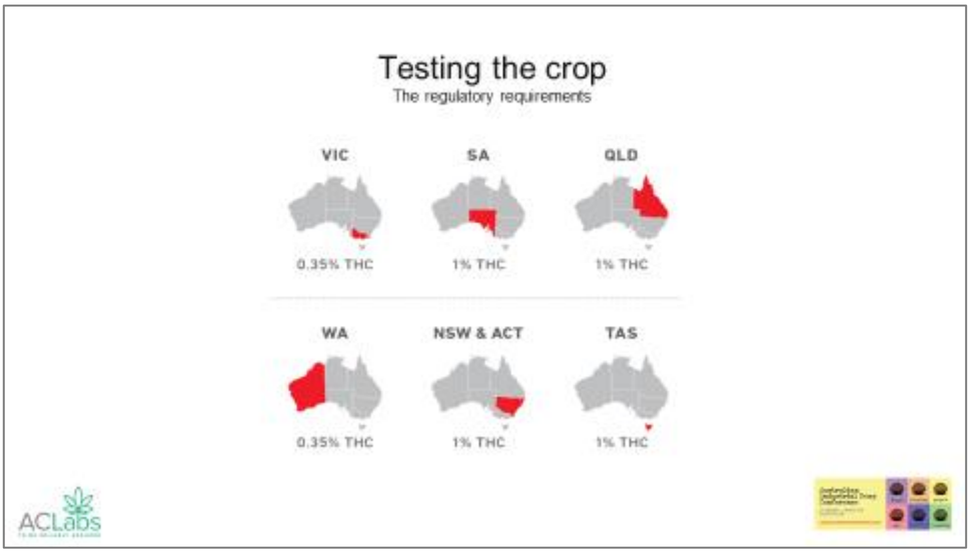

Testing the crop
The regulatory requirements
VIC
0.35% THC
SA
1% THC
QLD
1% THC
WA
0.35% THC
NSW & ACT
1% THC
TAS
1% THC
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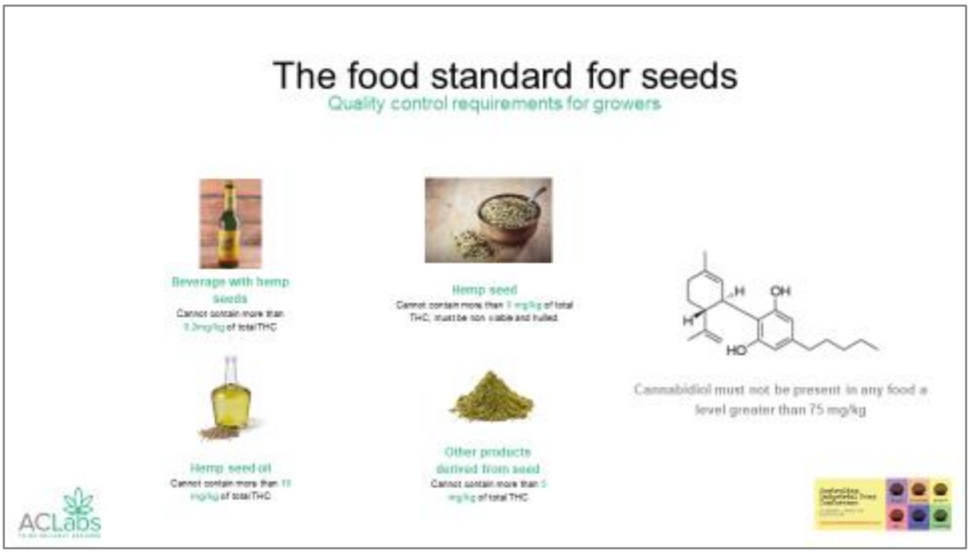

The food standard for seeds
Quality control requirements for growers
Beverage with hemp seeds
Cannot contain more than 0.2mg/kg of total THC
Hemp seed
Cannot contain more than 5 mg/kg of total THC, must be non viable and hulled
OH
H
H
HO
Cannabidiol must not be present in any food a level greater than 75 mg/kg
Hemp seed oil
Cannot contain more than 10 mg/kg of total THC
Other products derived from seed
Cannot contain more than 5 mg/kg of total THC
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Sampling in the field

How the levels are determined

- The sampling is performed when the seeds of the plant begin to ripen/or when the inflorescences of the plant are fully developed and matured
- **Equipment:** Garden shears, sampling containers, sacks known to be free from THC, sealing material, labels and sampling record.
- **Sampling:** Sampler always walks at right angles to the rows of the plants, cutting off at least 60 inflorescences at random but at expedient distance. This is the **Composite sample**
- The entire fruit bearing plant is used as a sample, and the cut is made underneath the inflorescence
- The inflorescences are taken arbitrarily from the composite and divided into two sacks, with at least 30 per sack. One is identified as containing test specimens, and the other as set-aside specimens that shall be kept by the hemp grower.

Source: UNDOC

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Hemp testing in the laboratory

Lab testing plays a pivotal role in compliance ensuring both grower and consumer confidence.

The lab can be seen as a "Gatekeeper" to ensure hemp foods meets the expectations of all stakeholders.

The lab seeks to independently verify compliance to the required FSANZ standard (Section 92 FSANZ Code 1991 Standard 1.4.4) and state agriculture regulatory requirements.

Total THC (THC & THC-A) and total CBD (CBD & CBD-A) through standard protocols and procedures.

ACLabs operates out of a NATA accredited facility (ISO-17025) which has a quality management system (QMS) in place. A QMS is central to the function of the laboratory as it,

- Prescribes how analytical tests are conducted
- Address issues of compliance and non compliance
- Facilitate corrective actions and review
- Sets criteria for selecting suppliers
- How method validations are conducted
- Identifies gaps in its operations to name a few

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Hemp testing in the laboratory (2)

In relation to the technical side of its operation namely of Hemp Testing, a laboratory must have a set of essential documented protocols (**Standard Operating Procedures- SOPS**) which will assist in the reliable execution of the chosen method.

Method Selection

Standardized - ISO/AOAC/ASTM or peer reviewed with validation data
Or
In-house

Method Selection is then governed by a number of other considerations

1. Analyte - Available Standards/ Permits/Affordability/ Security of storage
2. Available Equipment- HPLC /GC or GCMS and LCMS or LCMSMS
3. Available expertise- Do you have staff competency?
4. Sample Throughput- How many samples can you run in any set period
5. Method Sensitivity - can do get to the levels being asked
6. Method Selectivity - is your method measuring your interested compounds in the absence of other interferences?
7. Can you method cope with different hemp foods - seeds/muesli bars/beverages/oils
8. Cost per samples- The different matrices in which hemp will be allowed will dictate lab costs- No one universal method
9. Can your method validation be NATA accredited ? Have you done enough?

The Method must be fit for purpose

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How the seeds are tested

- Sample Submission – a chain of custody (COC) is submitted prior to arrival at laboratory, and sent with the samples. A COC is a vital documented unbroken evidence of the transfer of sample to a lab a request for services.
- Storage established - low light, refrigerated and tamper proof storage
- Appropriate analyst is assigned to job (proficient with the method)
- Seeds are ground and extracted, and portions are taken for moisture and testing.
- Extraction method - industry standard method with a proven track record (a version of QuEChERS)
- Homogeneity of the samples is important, and buffered salts are introduced to create the partitioning (to separate the analyte of interest)

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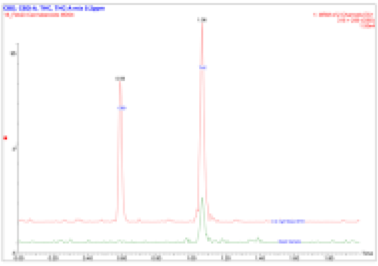
How the seeds are tested (2)

Instrumentation used: GC-MS or LC-MS/MS

Our extraction method is more suited to LC-MS/MS, however understanding of matrix effects is important.

Deuterated standards are used to correct for matrix effects, either the suppression or enhancement of the signal which can be problematic.

Analytes are measured against certified standards represented in a chromatogram to determine concentration and definitive identification in the original submitted sample.



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Method development

Analytical challenges with food

- Unknown matrices can be challenging to build assays around e.g. novel foods, recipes, complex mixtures e.g. candies, edibles, nutrition bars, beverages, cosmetics.
- Extracting the compound of interest (for analysis) can be difficult or the nature of the analyte can be altered - and it doesn't show up on the instrumentation.
- Food mixtures present unanticipated matrix effects which require extensive **problem solving capability** e.g. matrix suppression/enhancements, peak masking
- External pressures for quick results can lead to unforeseen complications in the method which could lead to erroneous results.
- Method development requires high calibre and experienced skill sets to solve unique problems.

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The need for QA/QC data

Validating and verifying methods

Method verification

Verification is the process of demonstrating the performance criteria included in the method can be meet by the facility prior to introducing them for routine use.

Method Validation

Systematic approach to establishing the performance characteristics and limitation of the method and identification of the influences that may change these characteristics and to what extent.

Required to establish that a test method consistently produces reliable analytical results

More rigorous and required for new test methods by assessing authorities

Validation

Parameters measured in a validation are:

- Linearity of Response
- Method precision: Closeness of agreement of measured quantity obtained by replicate measurements on the same object.
- Accuracy: Closeness of agreements between measured quantity and the true quantity.
- Limit of Detection (LOD) – The levels at which THC is detected.
- Limit of Quantitation (LOQ) - Usually 3 X LOD or at a concentration which is reliably measured.
- Selectivity - Does the method define the species that gives rise to the quantitation signal?
- Ruggedness (reproducibility)

a. What happens when the analysis is performed by a different chemist
b. What happens when analysis is performed by a different lab
c. What happens when analysis is performed 2 weeks apart
d. There are small changes in the method - smaller sample mass are weighed

- MU - Measurement Uncertainty

In plain English it is "the experimenters best estimate of how far an experimental quantity might be from it true value"

Other testing for food

Not covered by the food standard

Other contaminants may also exist in hemp foods (not covered by the food standard)

- Metals
- Mycotoxins
- Pesticide/herbicide residues
- Microbial contamination
- Foreign bodies
- Stability testing of packaged hemp

Testing and evidence of **Certificates of Analysis** of the above may be required by local and international regulatory bodies for approval.

Certificates of Analysis

How they can promote your product?

- **Authentication**
  Independent CoA can confirm specification/purity/regulatory compliance of product
- **Marketing**
  Certificates can be used to market the product purity - third party testing is integral to this
- **Clearance**
  Often required by foreign regulatory bodies to ensure they meet national and international standards

About us

Australian Cannabis Laboratories (ACLabs) is a company focused on ensuring quality control for the cannabis and hemp industries respectively.

We offer an independent quality testing service within the framework of the existing regulations concerning food (FSANZ), fibre and medicine (TGA).

Our mission

Establishing **Quality Control** for safer food and medicine

Industrial hemp cultivar evaluation – trials vs commercial experience Down Under

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Keywords: industrial hemp, establishment**,** grain yield, kg DM/ha

Abstract
Midlands Seed Ltd has been evaluating Industrial Hemp in New Zealand since 2001 and in Tasmania, Australia since 2012. Over this period there have been 11 cultivar evaluation trials for grain and dry matter production. This work has led to the registration of nine approved cultivars in New Zealand (approval not required by Australia) and the commercial production of 265 ha of hemp grain production in 2016-17. Cultivar evaluation has been critical to successful commercial production. There is a wide range of genetics available including grain, dual purpose and fibre types, which maybe dioecious or monoecious. Cultivar selection has been based on agronomic measures including crop establishment vigour, tolerance to disease, resistance to lodging, relative maturity, final height and grain or dry matter yield. Oil content and fatty acid profiles have also been measured. Grain yield trials in New Zealand have produced up to 2259 kg/ha of machine dressed seed. While whole plant dry matter yields of 15.5 TDM/ha have been achieved. Commercial grain yields in New Zealand have ranged from 0 – 1100 kg/ha and 0 – 930 kg/ha in Tasmania (harvest 2013 – 2017). Complete crop failure in commercial fields has occurred from time to time due to either poor stock seed quality, inadequate seedbed preparation or insufficient weed control. Current genetics available offer an acceptable range of maturities and agronomic characteristics including yield potential for production at latitudes around 43°S. Further improvement in consistent grain yields should be achieved with refinement of time of sowing x irrigation x nitrogen fertiliser management for the various cultivars. Improving crop standing ability, disease management and bird control will also be important.

Introduction
The production of industrial hemp (*Cannabis sativa* L.) was legalised with limitations on end use in New Zealand in 2001 and more latterly in Australia, with simplifying of the process occurring there with the passing of the Industrial Hemp Bill in 2015 [1]. There appears to be 101 uses of both the fibre and grain produced by industrial hemp [2]. However there has been limited opportunity to produce any products of hemp origin in New Zealand or Australia up until now. The fibre industry has faced a 'chicken and egg' situation where there has not been enough fibre available to warrant the development of significant processing capacity, but without the processing capacity there has been little incentive to produce a lot of fibre. The grain industry has been stilted because it has only been legal to sell hemp oil into the human consumption market, with all other seed-products destined for the stockfeed industry. Both countries have or are the process of passing new legislation (2017-18) to legalise the production and consumption of industrial hemp seed products for people. It is hoped this will pave the way for both industries to grow significantly [3].

Industrial hemp has been cultivated in Asia and Europe for centuries and more recently significant areas of hemp grain production have been grown in Canada. Europe/Asia predominantly grow hemp for fibre production, while Canada who had 55,854 ha grown in 2017, has focused on grain for human consumption [4, 5 and 6]. There are useful growing recommendations covering cultivar selection, sowing rates, fertility requirements and harvest procedures [4, 7]. Data on cultivar suitability and crop management in zones closer to 40-45°S is scarce.

Midlands Seed Ltd in Ashburton, New Zealand (43.9°S) has been evaluating numerous industrial hemp cultivars and crop management practices since 2001. This paper summarises a number of cultivar evaluation field trial results and initial commercialisation experiences in New Zealand and Tasmania, Australia (41.4°S).

Field Trial Methodology

Cultivar evaluation trials were established within commercial fields, using a small plot coulter drill with 15 cm row spacings. Depending on the year and/or site, sowing took place between mid-October and mid-December. Target populations were generally 150 – 200 plants/m^2 for grain yield trials and 250-300 plants/m^2 for dry matter (DM) production trials. All trials consisted of 3 – 4 replicates set out in a Randomised Complete Block (RCB) design. Grain yield trials were either, hand-cut and processed through a stationary thrasher (early years), or direct harvested using either a Wintersteiger Elite Plot Harvester or Sampo SR2010 Plot Combine. DM production plots were cut using a petrol disc cutter 10 cm above the soil surface.

Trial sites varied from year to year as did base fertility. Most trials received a base pre-plant incorporated fertiliser of 200-250 kg/ha Cropmaster 15 (15:10:10:12) and little to no post-emergent fertiliser. All except one trial were conducted in the South Island between Rakaia (43.8°S) and Timaru (44.4°S). The one North Island trial was conducted on an organic farm in the Wairarapa region (41.3°S). Successful commercial productions have been conducted in these regions and throughout Tasmania (41.4°S).

Except for the North Island trial, all sites were irrigated. Irrigation decisions were made by the co-operating grower based on the surrounding commercial field requirements. No herbicide or pesticide applications were made. Plot boundaries were maintained with Glyphosate or hand weeding. Bird netting was applied after flowering to prevent significant losses to birds due to differing maturities. Harvest date was dependent on cultivar relative maturity, the aim was to harvest plots when 80% of the seed had changed to a grey mottled colour. Harvested seed was immediately dried down to below 8% moisture content (%MC). Dry samples were cleaned using a Pektus Mini 80 machine. Screens were either a 5 mm round over a 1.6 mm slotted screen or a 4 mm round over the same slotted screen depending on seed size. Final machine dressed yields are adjusted to 8 %MC. Whole plant samples were chopped into 1-2 cm lengths and packed into air-tight bags prior to sending for analysis. Dry matter (DM), Metabolisable Energy (ME) and Digestibility were determined by an independent laboratory using standard practices.

Results & Discussion

Plant populations ranged from as low as 57 plants/m^2 to 278 plants/m^2 for grain production trials even though target populations ranged from 150-200 plants/m^2 (Table 1). Seed germination, TSW and estimated emergence were taken into account when determining sowing rate of each cultivar in each trial. There were major differences between years, i.e., Kelliher 2012-13 vs Kellier 2013-14 and significant variation in plant establishment between sites in the same year, i.e., Kelliher 2013-14 vs Taylor 2013-14.

Previous work by Townshend & Boleyn [8] indicated that grain yield was stable over a range of plant populations when trialing the dual-purpose cultivar Fasamo. The greatest difference in yield was between sites and not between plant populations. This suggests that other aspects associated with the growing environment or crop management are more influential on seed yield than the established plant population.

Midlands Seed Ltd has experience in growing over 30 crop species commercially including hybrids, many of which have been trialled in-house prior to commercial production. No other crop has proven more difficult to perfect recommendations on establishment conditions than for that of industrial hemp. Trial experience suggests that the following factors are critical to obtaining target establishment populations: High seed quality, sowing depth no greater than 35 mm, freedom from soil compaction and removal of imperfect drainage. For commercial grain production, populations around 150-200 plants/m^2 ensure good early ground cover, reducing weed germination. Plants at these populations also have fine to moderate stem diameters and seed heads which are held in the top 50% of the stalk, which facilitate harvesting.

Table 1: Summary of established plant populations (plants/m^2) across eight grain trial sites over five years.

Established Plant Populations for Industrial Hemp Trial Sites (2006 - 2014) - plants/m^2								
Year	2006-07	2007-08	2012-13	2012-13	2013-14	2013-14	2013-14	2014-15
Site	PPCS[2]	MacKenzie	Kelliher	Taylor	Kelliher TOS 1	Kelliher TOS 2	Taylor	Taylor
Sown	10.11.06	1.11.07	1.11.12	22.11.12	21.10.13	18.11.13	11.11.13	8.12.14
Fasamo	154	255ab	57	172abc	184d	151cd	88	205a
Finola	208	278a		149c	198c	154bcd	96	
USO31	193	206bc	85	180ab	258a	219a	107	203a
CFX-1				179abc	224bc	185b	116	199a
CFX-2				156bc	259a	180bc	102	195ab
CRS-1				182ab	199cd	163bcd	111	172b
Fedora 17	209	242ab	107	161bc				
Felina 32	213	182c	76	199c				
Ferimon 12	204	244ab	75	179abc	235ab	178bc	88	171b
Santhica 27	334							
Epsilon 68	277		90	160bc				
Futura 75	311		90	162bc	197cd	142d	104	
$LSD_{(0.05)}$[1]	ns/ns	44	ns	30	30	31	ns	25
CV%	13.7/16.4	12.5	15.8	12.8	9.4	12.3	18.9	8.6

[1] - Fishers protected LSD test at P=0.05. Numbers followed by the same letter are not significantly different from one another.

[2] - Different target populations for oilseed types and fibre types, populations sets analysised seperately.

Significant differences in grain yield between cultivars tested was also experienced. Differences between sites and years was again evident (Table 2). Depending on the year and site, harvest by direct heading was completed from late February through to late March. Differences in grain yields between cultivars evaluated should only be compared at individual sites as not all cultivars were evaluated at all sites over the test years.

The best grain yields were achieved at the MacKenzie site in 2007-08 where Ferimon 12 produced 2259 kg/ha MD, which was not significantly different to either Fedora 17 or Felina 32. All three of these cultivars are monecious fibre types. The plots in this trial were cut by hand and fed through a stationary combine, this method may have artificially increased realistic direct harvested yield potential. Dual purpose and specialty grain types performed well at Taylors in 2012-13 and in the second sowing date trial at Kellihers in 2013-14. In these trials the taller, later maturing fibre types tended to report lower yields. This was often due to seed loss occurring when bird netting was removed as these cultivars tend to grow taller and up through the netting.

Table 2: Summary of machine dressed (MD) hemp grain yields (kg/ha) adjusted to 8%MC across eight sites over five years.

Machine Dressed Hemp Grain Yield (kg/ha) Adjusted to 8% Moisture Content								
Year	2006-07	2007-08	2012-13	2012-13	2013-14	2013-14	2013-14	2014-15
Site	PPCS	MacKenzie	Kelliher	Taylor	Kelliher TOS 1	Kelliher TOS 2	Taylor	Taylor
Sown	10.11.06	1.11.07	1.11.12	13.12.12	21.10.13	18.11.13	11.11.13	8.12.14
Fasamo	699	1610a	817	648cd	431a	933cd	595c	679a
Finola	648	1518a		866b	111f	1049bc	159d	
USO31	518	1944b	547	690c	320cde	1123ab	826a	620ab
CFX-1				1104a	227d	1242a	543c	465c
CFX-2				986ab	209ef	1217a	753ab	497c
CRS-1				865b	342cd	1260a	682abc	537bc
Fedora 17	940	2096c	399	262f				
Felina 32	1074	1979c	454	367ef				
Ferimon 12	1143	2259c	397	458e	721a	878d[2]	827a	737a
Santhica 27	806							
Epsilon 68	913		330	453e				
Futura 75	829		238	377ef	483b	526e[2]	665b	
$LSD_{(0.05)}$[1]	220	307	n/s	160	134	129	155	119
CV%	14.4	10.7	20	17.4	25.8	8.6	16.8	13.5

[1] - Fishers protected LSD test at P=0.05. Numbers followed by the same letter are not significantly different from one another.

[2] - Yield loss occured due to damage when removing bird netting and Ferimon 12 also over mature.

There is a trend indicating that higher grain yields are achieved when late maturing types (Fedora 17, Felina 32, Ferimon 12, Santhica 27, Epsilon 68, Futura 75) are sown early (Oct/Nov) and when early maturing types (Fasamo, Finola, USO31, CFX-1, CFX-2, CRS-1) are sown later (Nov/Dec).

Grain yields have not been adjusted for plant population and further correlation analysis between established plant population x grain yield across sites and years has not been completed. However, the data presented in Tables 1 and 2 suggest it is not likely to be a strong relationship; grain yields were poor at Kellihers TOS 1 site in 2013-14 which had very similar populations to the highest yielding site of MacKenzie in 2007-08.

The range in grain yields experienced in field trials is a good reflection of the range in yields that can be expected in commercial productions depending on the successfulness of crop establishment and harvest (Table 3). Individual field yields have ranged from 0 kg/ha to 1100 kg/ha of MD grain. Complete crop failure has occurred when poor quality seed has been inadvertently sown or when weed control has been inadequate. Yields have been disappointing when crops have grown too tall, causing lodging in wind events and hampering combine harvesting. Further work to control crop height should be investigated or only cultivars that do not have height issues should be grown. Growing cultivars with no broadleaf herbicide tolerance in weedy fields is also a recipe for disaster.

Commercial experience has demonstrated that grain yields over 1 MT/ha are possible, however current experience suggests a realistic commercial yield target of 800 kg/ha is probably more appropriate until improved crop management advice can be provided.

Table 3: Summary of commercial machine dressed yields from 2013 to 2017 in New Zealand and Tasmania, Australia.

	TASMANIA			NEW ZEALAND		
	Area Sown (ha)	Yield Range (kg/ha MD)	Average Yield (kg/ha MD)	Area Sown (ha)	Yield Range (kg/ha MD)	Average Yield (kg/ha MD)
Harvest 2013	22	-	310	37	510 - 970	745
Harvest 2014	49	0 - 930	350	45	410 - 940	655
Harvest 2015	71	-	850	114	100 - 1000	335
Harvest 2016	85	500 - 900	635	30	160 - 750	480
Harvest 2017	185	500 - 600	585	80	340 - 1100	585

Table 4: Summary of Thousand Seed Weight (TSW), Oil Content and Fatty Acid Profile of hemp cultivars harvested at Taylors 2012-13.

Cultivar	TSW (g)	Oil Content (%m/m)	Linoleic (%m/m)	Alpha Linolenic (%m/m)	Gamma Linolenic (%m/m)
Fasamo	11.3	32.4	53.4	21.3	3.5
USO 31	14.4	35.5	55.0	17.9	3.3
Ferimon 12	12.7	35.9	55.7	17.9	3.6
Fedora 17	14.0	34.6	55.6	18.3	3.4
Felina 32	11.6	36.2	55.6	18.5	3.3
Futura 75	12.3	34.5	55.4	18.7	2.8
Epsilon 68	12.9	35.8	56.4	17.8	3.0
CFX-1	15.9	34.6	54.9	17.8	3.7
CFX-2	15.3	34.7	55.1	17.7	3.8
CRS-1	15.5	33.9	54.6	18.2	3.2
Finola	11.3	33.6	54.6	18.7	4.4

Bulked samples were taken across replicates for each cultivar in 2012-13 for oil content and fatty acid analysis (Table 4). Statistical analysis is not possible on bulked samples, so data should be used as a guide only. As expected TSW was variable between cultivars as this is strongly genetically determined. Compared to other results (data not presented) the TSW at this site appears to be about 1 g lower than normally expected for all of the cultivars reported. Felina 32 had the highest oil content (36.2%) while Fasamo the lowest (32.4%). A similar level of variation between cultivars is seen in the fatty acid profile with 2-3% difference covering the range in results.

Table 5: Comparison of dry matter (DM) yield and forage quality over two harvest dates for one dual-purpose and three fibre cultivars tested in 2007-08. Whole plant analysis conducted.

Cultivar	DM Yield 1st Cut (kgDM/ha)	DM Yield 2nd Cut (kgDM/ha)	DM Content 1st Cut (%)	DM Content 2nd Cut (%)	ME 1st Cut (MJ/kgDM)	ME 2nd Cut (MJ/kgDM)	Digestibility 1st Cut (%)	Digestibility 2nd Cut (%)
Fasamo	4575	4807c	27.4	34.6	7.9	7.5	49.3	46.7
Santhica 27	7655	11688b	25.1	33.9	7.9	7.4	49.1	46.1
Epsilon 68	7618	14556a	26.2	32.3	8.7	7.6	54.3	47.2
Futura 75	7599	15510a	24.8	32.5	8.3	7.0	52.1	44.0
LSD (P=0.05)[1]	n/s	1703	n/s	n/s	n/s	n/s	n/s	n/s
%CV	16.0	9.0	3.3	5.0	6.9	9.0	7.0	8.7

1 - Fishers protected LSD test at P=0.05. Numbers followed by the same letter are not significantly different from one another.

Dry matter (DM) yield and forage quality testing of three monoecious cultivars was compared to the dual-purpose cultivar Fasamo in 2007-08 (Table 5). This trial was sown on the 5th November 2007. The first whole plant forage harvest was taken just prior to flowering, 81 days after sowing, the second forage harvest was conducted at the 'soft dough' grain stage, 122 days after sowing. Plant populations were low, ranging from 88 – 109 plants/m^2, which did not differ significantly between cultivars (data not presented).

As expected the DM yield increased between cuts 1 and 2, with the only significant difference in all variables measured being the DM yields in the 2nd cut. There was up to a two-fold increase in DM yields for the fibre cultivars between the 1st to the 2nd cut, while the dual-purpose cultivar barely changed. The increase was driven by increasing biomass and DM content. As the crop matured (increased in DM content) both the ME and Digestibility decreased, resulting in poorer forage quality as the crop matured.

Maximum DM yields can be expected if a fibre cultivar is grown. Maximum DM production should occur if the crop is planted in late October/early November and harvested at the cheesy dough growth stage (early March) as whole crop forage. It will however be of low quality when compared to whole crop cereal silage (Table 6).

Table 6: Summary of comparative whole crop cereal silage crop option in Canterbury, New Zealand [9].

	BARLEY	OATS	WHEAT	TRITICALE
Maturity (days): (1) from sowing (2) flowering to 38%DM	 95 - 130 22 - 28	 110 - 140	 105 - 132 24 - 30	 112 - 135 27 - 32
Sowing - Harvesting	Sept – Dec	Aug – Jan	Aug – Jan	Aug – Jan
DM Yield (T/ha)	8 – 14	8 – 15	8 – 17	8 – 18
MJME/kgDM	9.5 – 10.5	8.5 – 9.5	9.5 – 10.5	9.5 – 10.5

A concurrent trial was run at the same site in 2007-08 to establish the effect of plant population on dry matter yield. The populations established were not as high as targeted (Table 7) but were significantly different from one another. At these lower than optimal plant populations (78 – 155 plants/m^2) there were no significant differences in whole plant DM yields at either cutting interval. Whether higher plant populations would have resulted in higher yields is not confirmed.

Table 7: Dry matter (DM) yields across plant populations at both the 1st and 2nd cut with cv. Futura 75 in 2007-08.

Treatment No.	Target Pop (pl/m²)	Established Pop (pl/m²)	Dry Matter Yield (kgDM/ha) 1st Cut	Dry Matter Yield (kgDM/ha) 2nd Cut
1	175	78d	7133	14902
2	200	90cd	7126	14042
3	225	101bcd	7541	14827
4	250	107bc	8045	14514
5	275	124b	7889	14299
6	300	155a	8069	14148
LSD (P=5%)[1]		23	n/s	n/s
CV		14.2	9	5

1 - Fishers protected LSD test at P=0.05. Numbers followed by the same letter are not significantly different from one another.

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Commercial breeding and selection of low THC *Cannabis sativa* L. for sub-tropical environments

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Keywords: Ecofibre, Ananda Hemp, Breeding, *Cannabis sativa* L, Seed Yield, Low THC, Rare Cannabinoids

Abstract

Hemp (*Cannabis sativa* L. 2n=20) is a sustainable and high yielding biomass crop that is widely considered as a short-day plant and in which day-length plays a major role in the timing of male and female flowering. Hemp originated in Central Asia. Hindustan and Europe/Siberia have been proposed as two centres of diversity. As a result of selection and breeding efforts in Europe and Canada, a number of modern seed and medicinal varieties that are well-adapted to temperate regions (higher latitudes) have been developed. Similarly, there has been a long history of hemp cultivation for fibre in China that has resulted in the development of fibre-type varieties suited to various latitudes. However, a limited number of commercial seed and medicinal varieties suited to tropical and sub-tropical regions are currently available.

Flowering time is a major determinant contributing to the adaptation of a variety to tropical and sub-tropical regions for successful commercial production. Over the last few years, our breeding efforts at Ecofibre have significantly escalated and have resulted in the development of regionally-specific hemp cultivars with optimal flowering period for different purposes. In this paper, we outline the current situation of the Ecofibre/Ananda Hemp germplasm enhancement and breeding program for sub-tropical and tropical regions for different applications.

Releases from the Ecofibre breeding program include a series of varieties (ECO_CHG PBR, ECO_CHY PBR, ECO_CHA PBR, ECO_MS77 PBR) and advanced breeding lines selected for adaptation between latitudes 42° north and south and to 11° south in Australia. The main breeding effort is to develop varieties with improved and unique attributes that are superior to existing commercial hemp cultivars and are stable under field environmental conditions. Recently, distinct but interconnected breeding sub-programs for each of the end-products (nutraceutical, food and fibre) have been developed to enhance trait-specific values contributing to enrichment of commercial end-products. At Ecofibre, varietal development that meets various end-user's requirement begins with the systematic characterisation of cannabis accessions for a number of traits. Hemp is a dioecious (and sometimes monoecious) annual open-pollinated species and requires a specific breeding approach.

Depending on the end-use application, different breeding strategies have been adopted. Seed yield and seed composition, chemical composition of the inflorescence and fibre characteristics are some of the traits targeted to suit commercial production at different latitudes. Success of our germplasm

enhancement and breeding program is in part owed to our gene bank which is widely recognised as the world's largest and most diverse privately-held genetic resource of cannabis.

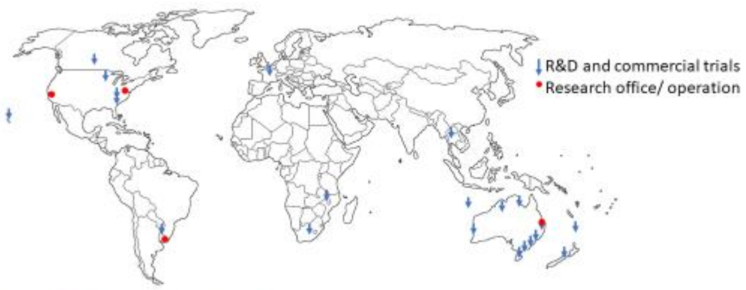
Introduction and modified-mass selection have been the two most common methods used in breeding hemp for seed (food) and fibre. Following the success of identifying trait-specific diversity within the Ecofibre gene bank, comprising of over 270 landraces and 1100 cultivars/ breeding lines, a new shuttle-breeding program across Australia and the US has been established to develop highly adaptive varieties with high yielding potential by testing in a range of growing conditions. High seed yielding breeding lines ECO_NEXT218, ECO_NEXT202 and ECO_NEXT222 with average seed yields of 2.46 t/ha (ranging from 1.88 to 3.66t/ha across three sowing times), 5.2t/ha (2.0 – 8.43t/ha) and 2.9t/ha (1.9 – 6.46t/ha) during the 2017 replicated plot trials in 41°S have been selected for further refinement. Average seed yield of known varieties Crag and ECO_Excalibur from the same trial were 0.75t/ha and 1.12t/ha respectively. ECO_NEXT222 line was one of the most promising with highest total protein (up to 600% more total protein than standard varieties) in a study conducted by the University of Adelaide (University of Adelaide, 2018 – unpublished data).

It is well-known that a few major genes control cannabinoid biosynthesis in hemp. Recently we have adopted a modified Marker-Assisted Recurrent Selection (MARS) technique to select female and male plants for high CBD/A and other rare cannabinoids. Accessions with high potential cannabinoid contents (e.g. high CBD/A) from the Ecofibre gene bank have been selected and sub-samples from each population have been chemo-typed. Considering traits such as maturity and height, parental lines that show some potential and fit in a regular breeding program have been selected for crossing and further evaluation and selection. As a result, individual lines high in a specific cannabinoid molecule or combination of cannabinoids have been identified. From earlier screening of low THC germplasm for cannabinoid content, individual breeding lines with natural CBD/A content of 9.23% w/w (dry weight), THCV/A of 2.98% w/w and other high quantities of rare cannabinoids (e.g. CBDV/A, CBG, CBC, CBN) have also been identified.

Ecofibre has made significant progress towards developing commercially viable, end-use targeted hemp cultivars suitable for large-scale production in tropical and sub-tropical regions. The work is on-going and will no doubt be refined as the industry and markets for hemp products evolve.

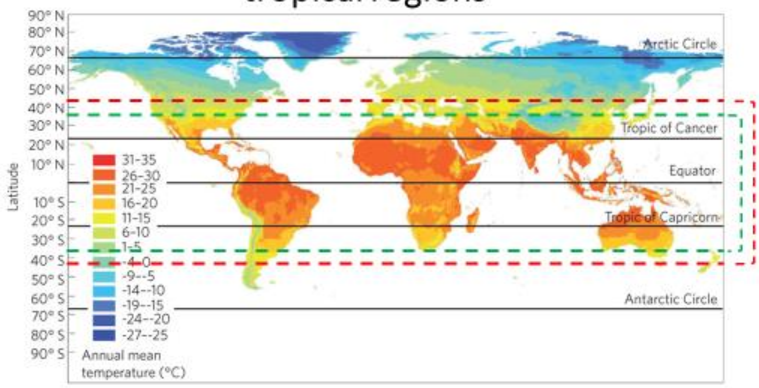
Acknowledgements
Ecofibre is grateful for the support and co-operation of its numerous research partners.

Partnership with leading organizations to address key research questions



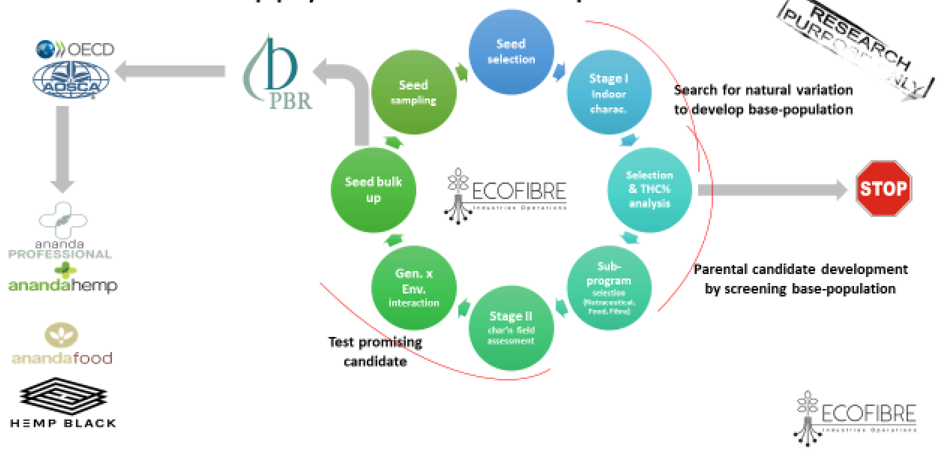
ECOFIBRE

Breeding focus on Tropical and Sub-tropical regions

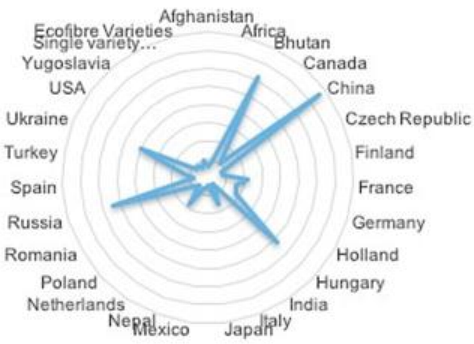


ECOFIBRE

R&D pipeline
Seed supply for commercial production



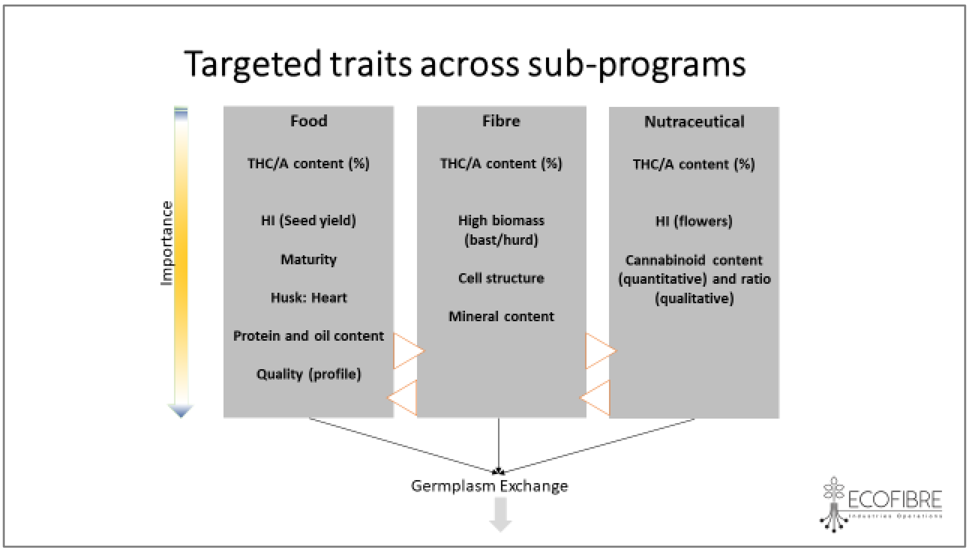
Ecofibre global genebank and Phase I characterisation

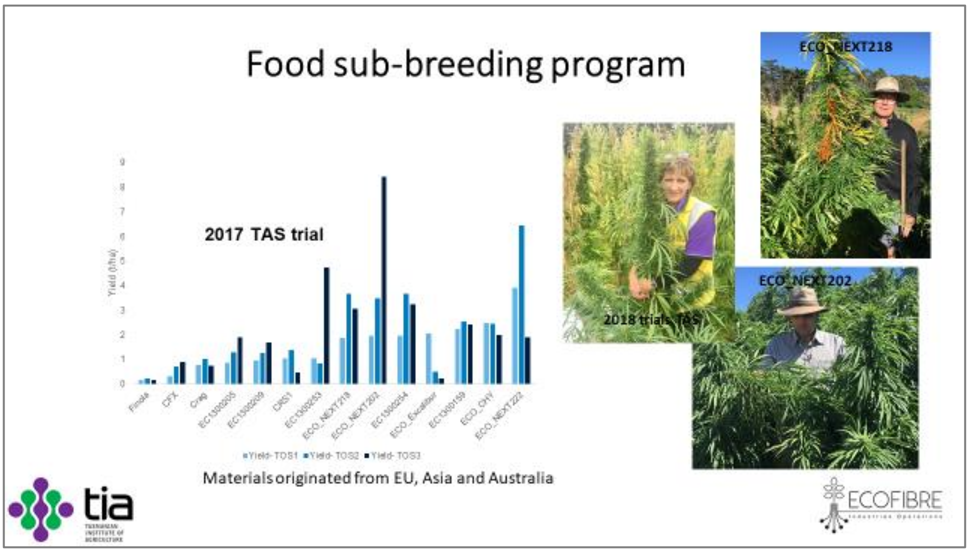


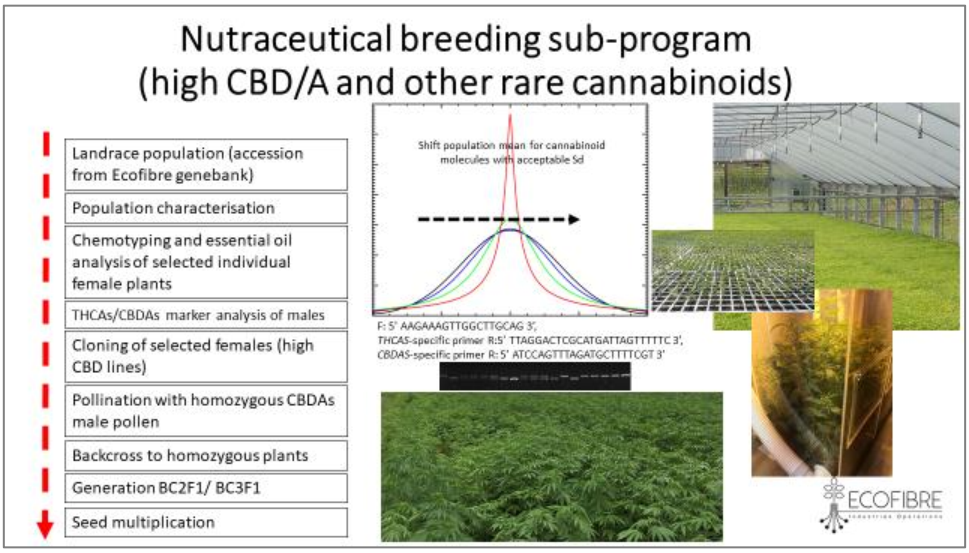
Southern Cross University

Fit for purpose breeding strategy

- Depending on the breeding sub-program (Nutraceutical, Food or Fibre) different approaches are adopted
  - Introduction and Mass selection: Materials from different regions including Canada, East-EU, West-EU, SE Asia, Australia analysed and tested at different latitudes.
  - Shuttle breeding program to develop highly adaptive varieties with high yielding potential by testing in contrasting growing conditions
    - Main sites: SE Qld, Tasmania, NSW and the US
      - Qld: high yield (irrigated in Aus), disease pressure, THC content
      - Tasmania: grain yield, adaptation (flowering time, etc.)
      - US: , high yield, adaptation, biomass, etc.
  - Marker-Assisted Recurrent Selection
    - Main focus on cannabinoids


Targeted traits across sub-programs
Importance
Food
THC/A content (%)
HI (Seed yield)
Maturity
Husk: Heart
Protein and oil content
Quality (profile)
Fibre
THC/A content (%)
High biomass (bast/hurd)
Cell structure
Mineral content
Nutraceutical
THC/A content (%)
HI (flowers)
Cannabinoid content (quantitative) and ratio (qualitative)
Germplasm Exchange
ECOFIBRE


Food sub-breeding program
2017 TAS trial
ECO_NEXT218
2018 trials TOS
ECO_NEXT202
Materials originated from EU, Asia and Australia
tia
ECOFIBRE


Nutraceutical breeding sub-program
(high CBD/A and other rare cannabinoids)
Landrace population (accession from Ecofibre genebank)
Population characterisation
Chemotyping and essential oil analysis of selected individual female plants
THCAs/CBDAs marker analysis of males
Cloning of selected females (high CBD lines)
Pollination with homozygous CBDAs male pollen
Backcross to homozygous plants
Generation BC2F1/ BC3F1
Seed multiplication
Shift population mean for cannabinoid molecules with acceptable Sd
F: 5' AAGAAAGTTGGCTTGCAG 3',
THCAS-specific primer R:5' TTAGGACTCGCATGATTAGTTTTTC 3',
CBDAS-specific primer R: 5' ATCCAGTTTAGATGCTTTTCGT 3'
ECOFIBRE

Nutraceutical – commercial product development

ECOFIBRE

Fibre breeding sub-program

- Low THC fibre varieties with specific hurd/bast characteristics (sustainable and resilient product)
- Launch version 1.0 of Hemp Black in 2018
- In the process of development and design of pyrolysis process and equipment

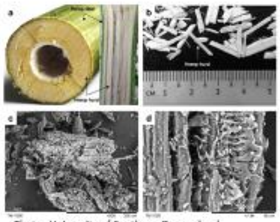


Photo: University of Southern Queensland

Photo from Ecofibre-supported MSc student Rhia Stanger at Southern Cross University

ECOFIBRE

Fibre – commercial product development

- Low THC fibre varieties with specific hurd/bast characteristics (sustainable and resilient product)
- Launch version 1.0 of Hemp Black in 2018
- ECO_CHG

Thomas Jefferson University
THE LAMBERT CENTER FOR THE STUDY OF MEDICINAL CANNABIS AND HEMP

Jefferson

ECOFIBRE

Acknowledgement

- Colleagues at Ecofibre, Ananda Hemp, Hemp Australia and others
- Special thank to
  - Phil Warner, Steve Walsh, Tim Shapter
  - All collaborators

"Of all the plant species on the planet, cannabis has the sole capability to sustain and enrich human life indefinitely."

Philip S Warner 2018

HEMP BLACK ananda food ananda PROFESSIONAL ananda hemp

tia Jefferson PhilaU University of Southern Queensland Universidad de la República Uruguay UK Kentucky Southern Cross University The University of Sydney Victoria Department of Economic Development, Jobs, Transport & Resources Northern Territory Government Murdoch University The University of Adelaide CSIRO

ECOFIBRE

Industrial hemp production trials in Tasmania

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Abstract
Recent changes in legislation in the Australian State of Tasmania in addition to changes in Australian Federal law has seen a renewed interest in the production of grain hemp for human consumption in Tasmania. For grain hemp to become established in the high-input high-output rotational cropping systems in northern Tasmania production efficiencies are required to generate attractive gross margins. While research on agronomy is also needed, this study evaluated the adaptation of both known dual purpose grain cultivars and land races from other regions of the globe. Fifteen lines were planted on three occasions; 25th November and 9th December 2016, and 2 January 2017 at the Tasmanian Institute of Agriculture Vegetable Research Facility. Lines were primarily evaluated against estimated gross yield, the coefficient of variation in yield, plant height and harvest index. Of these lines, **EC1300254**, **ECO_NEXT218**, **ECO_NEXT202**, **EC1300159** and **ECO_NEXT222** all demonstrated significant potential to consistently provide gross yields above 2 t/ha, perhaps as high 8 t/ha in the cool temperate climate of Tasmania.

Introduction
Successful continued development of a hemp seed industry in Tasmania will depend on the establishment of viable markets and well-defined supply chains where both comparative and competitive advantages have been identified, and where the return on investment to each participant is profitable at each stage during production, processing and distribution. A primary tool used by farmers to assess the return on investment for a particular cropping option is a gross margin analysis, typically expressed as income less variable costs per unit of land. Estimated gross margins in 2017 for irrigated rotational cropping enterprises in Tasmania ranged from $530 /ha (grain canola) to $10,590 /ha (seed potato) and a median of $3,140 /ha (Mary Bennet, 2017). The gross margin not

only determines if a crop is grown, but also its priority in the allocation of resources during periods of peak demand. The 2017/18 season price for grain hemp in Tasmania is currently around $3500/t, and the estimated average yield of clean dried seed at 1 t/ha. Less variable costs of $2,304/ha including irrigation, harvesting, cleaning and drying, our estimate of the current gross margin for hemp is $1,195/ha. This ranking in the line-up of crop gross margins makes grain hemp a less competitive alternative to other more lucrative crops grown within the intensive cropping rotations of northern Tasmania.

Improving the profitability of grain hemp as an alternative enterprise in the cropping rotation will require either an increase in profits driven by the price of grain and/or productivity growth driven by input efficiencies or improved yields. Growers selling at the farm gate are typically 'price takers' with little or no control over input costs nor the income generated per unit of product. Hence profit gains are typically driven by improvements in net yield. While agronomy provides a key role in the improvement of crop productivity, the primary determinant of yield potential is set by genetics.

To identify opportunities to increase net yield this study evaluated the phenotypic expression of 16 dioecious lines of hemp with heritages across Indo-China, Asia and Europe and which included recognised dual purpose varieties **Finola**, **Crag, CFX**, **CRS-1** commonly grown in Canada from ca. latitudes 48°-51°N and; Ecofibre Industries (Maleny, QLD, Australia) lines **ECO_CHY** and **ECO_CHG** (fibre variety) and **ECO_Excalibur**, this latter variety the main commercial grain line grown by Ecofibre Industries in Tasmania. While the cultivars used in Canada are derived for production at latitudes higher than Tasmania (41°-43°S) and hemp is recognised as clinal [1], this study was purposed to establish if these or the land race accessions could be adapted to the Tasmanian climate and photoperiod. Of paramount consideration was the identification of genetic material that would increase gross crop yield above 2 t/ha to increase gross margins, and stability of yield, for which we used a coefficient of variation in yield below 50% as criterion. The study also considered plant stature and the stalk:seed ratio (harvest index) as these are also attributes important to production systems designed for crops of short stature.

Methodology

The adaptation trials were conducted at the Tasmanian Institute of Agriculture Vegetable Research Facility ('Forthside') located on the central northern coast of Tasmania, Australia (41°12'11.55"S, 146°15'50.26"E). The climate at this location is considered as cool temperate with 1100mm, predominately winter rainfall. Summer days are warm with cool nights and the solstice photoperiod ca. 15 hours and 21 minutes. Soil at the research facility is a deep red earth (Ferrosol group), well-drained, well-structured and chemically fertile.

Three experiments located within a commercial crop of **ECO_Excalibur** were conducted on three different planting dates, and each structured as a single factor design; cultivar with 14 levels. Cultivars were planted in a randomised complete block with four replicates. Planting dates were selected when the photoperiod extended beyond 14 hours (late October) and seed was sown in late spring on the 25th November, early summer on the 9th December 2017, and mid-summer on 2nd January 2017. The accessions / cultivars evaluated were **CFX**, **ECO_CHY**, **CRS-1**, **Finola**, **ECO_Excalibur**, **EC1300159**, **ECO_NEXT202**, **EC1300205**, **EC1300209**, **ECO_NEXT218**, **ECO_NEXT222**, **EC1300253**, **EC1300254**, **CRAG**, **ECO_CHG, Zolo11** and the seed was provided by Ecofibre Industries (Maleny, QLD, Australia). Fifteen accessions are listed as **ECO_Excalibur** was swapped with **ECO_CHG** in the January planting.

The soil bed was prepared using a power harrow and seed was sown by hand at a depth of 15mm and at a density of 100 plants/m^2 in plots 2m wide and 1.7 metres long. Due to limited seed availability, only the three centre rows were sown with the test variety, and the outer rows seeded with **ECO_Excalibur**.

Data recorded included the first day of germination, final plant stand density, daily counts of male flowers, plant height at harvest (mm) for 5 random plants per plot, and whole plot yield (g/plant). Grain from each entire plot was dried to approximately 9% moisture content, threshed and cleaned, and then weighed (g). Whole plot yield was converted to an estimated yield (t/ha) assuming a plant stand density of 100 plants /m^2, and a sex ratio of 50:50 (e.g. 500,000 female plants/ha). A harvest index was calculated using the ratio of seed:stem dry weights (g).

Statistical Analysis
All statistics were conducted in R [2]. Where the model assumptions of normality and homoscedasticity of the residuals were met, lmer, a linear mixed effect model was used [3]. The linear models included cultivar and planting date as fixed effects, while block was specified as a random effect with intercept. Where the data failed the linear fixed effect model assumptions, the non-parametric Freidman test (prentice.test) was used [4] as this approximates a one-way analysis of variance with blocking. Logistic models were fitted to cumulative male flowering using the stat_growthcurve and fit_growth_ functions using the add-on growthcurve [5] to the package ggplot2 [6].

Results
Establishment
The days to first germination (Fig.1) for the majority of cultivars declined as planting dates progressed from late spring to mid-summer (Freidman, p<0.001). Mean (± sd) first appearance was 10.9 ± 0.7 days in November, 8.8 ± 1.2 days in December, and 5.8 ± 1.3 days in January, although this latter mean was leveraged by the slow emergence of **Zolo11** (Freidman, p<0.01).

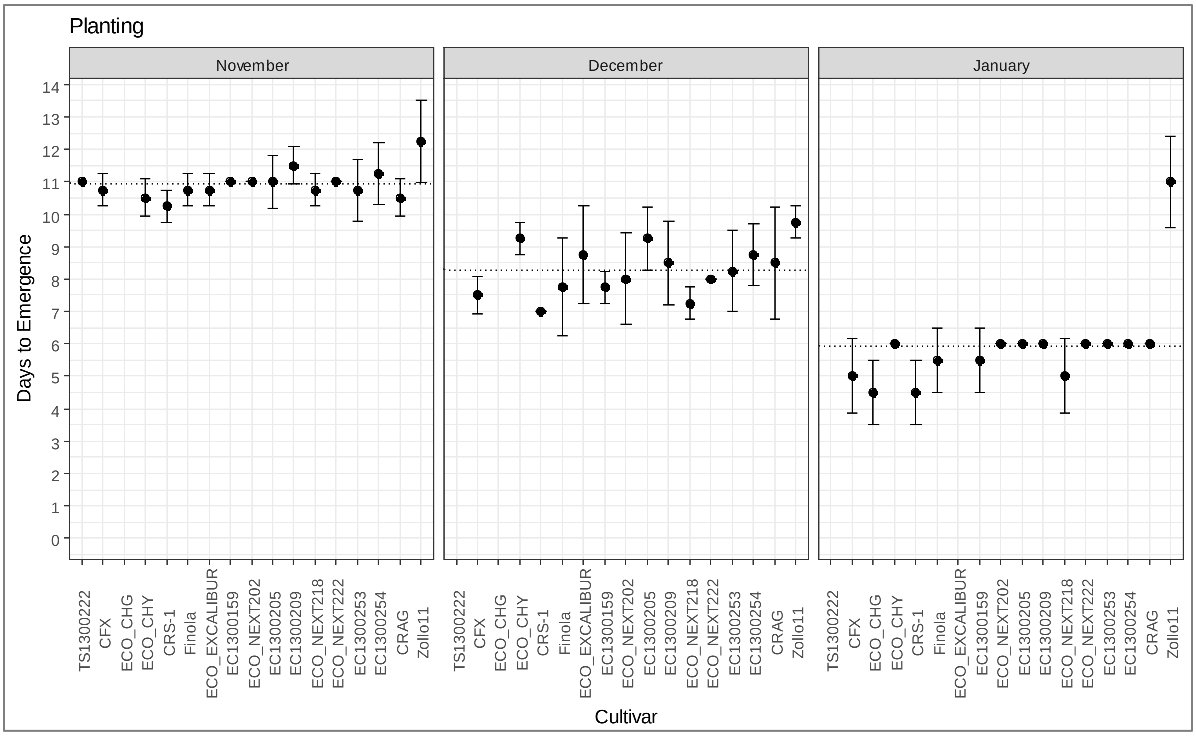

Figure 1. Mean number of days to first emergence for 17 industrial hemp accessions planted on the 25th November 2016, 9th December 2016 and 2nd January 2017 at Forthside on the north coast of Tasmania, Australia. Error bars = standard deviation.

Male Flowering
For those lines planted on 25th November six of these (**CFX, CRS-1, Finola, ECO_Excalibur, ECO_NEXT218** and **CRAG**) had all begun male flowering by 39 DAP. The median days to male flower appearance in this planting slot was 43 days and the last to flower was **EC1300205** at 80 DAP. Planting 2 weeks later on the 9th December did not influence the median time to flowering which remained at 43 DAP however the 6 earliest flowering lines from November all flowered 10 days earlier at 29 or 30 DAP. Cultivar **ECO_CHY** took the longest to flower when planted in December, with male inflorescences appearing 69 DAP. Planting on 2 January 2017 reduced the median time to flowering by 5 days (38 DAP) albeit the earliest lines (as above but excluding **ECO_Excalibur**) still only flowered at 29 DAP.

The logistic growth patterning (Fig. 2) of cumulative male flowering for cultivars **CFX**, **CRS-1**, **Finola** and **ECO_NEXT218** showed little shift in response to planting times while other lines such as **EC1300205** and **EC1300253** exhibited a distinct phase shift. The asymptote of each logistic curve is representative of the sex ratio (Male:Female) and this ranged from 0.39-0.43 (**Finola**) where female inflorescence production was favoured, to fully male (**ZoloII**) in the first two plantings, and 0.69 in the January planting (**EC1300209**).

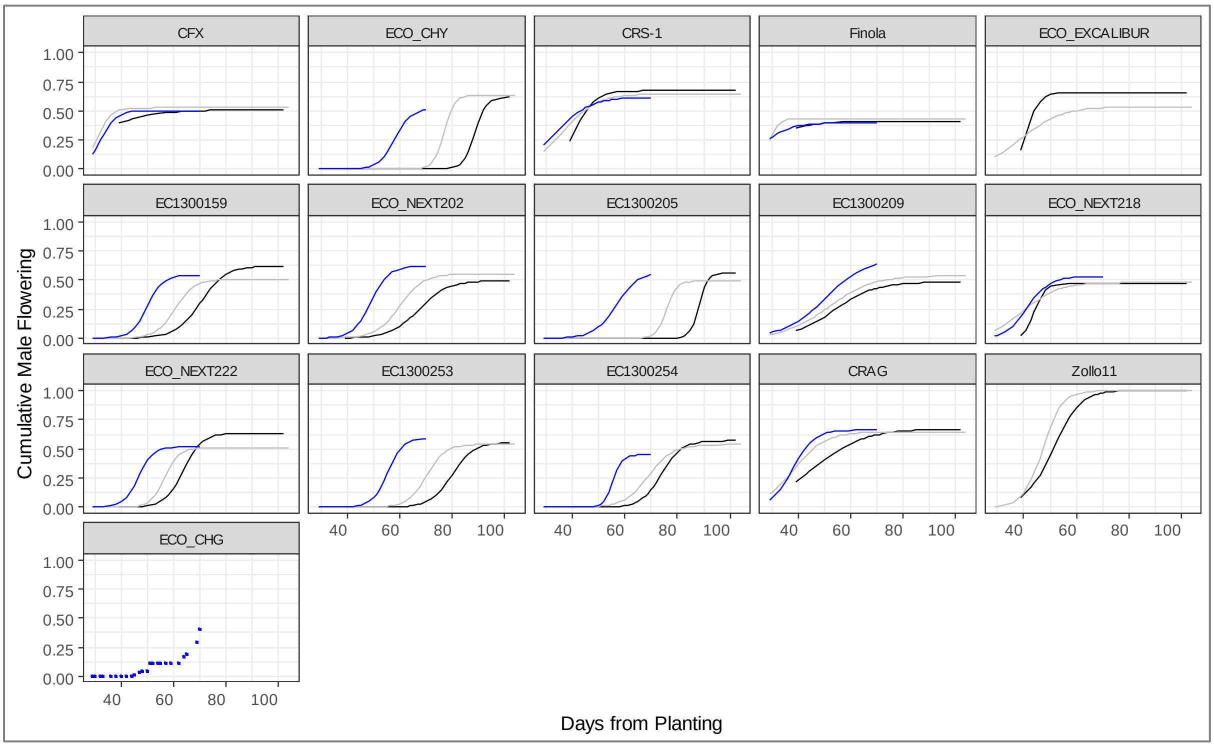

Figure 2. Logistic growth models of cumulative male flowering against days after planting for 15 industrial hemp accessions planted across three dates, 25th November 2016 (black), 9th December 2016 (grey) and 2nd January 2017 (blue) at Forthside on the north coast of Tasmania, Australia. Cumulative flowering is expressed as the mean proportion (n=4) of the total number of plants in each plot. The asymptote where reached is indicative of the final sex ratio. All fits were significant (p <0.001) although a suitable fit could not be found for ECO_CHG.

Yield, Height and Harvest Index
Line performance was benchmarked against the magnitude of yield, yield variability, plant height and harvest index, with a >2 t/ha magnitude and a Coefficient of Variation (CV) <50% used to establish a four quadrant matrix (Fig. 3). Hence those lines falling in the bottom right quadrant were viewed as more favourable candidates for future breeding. Measured yields against planting time appear in Table 1.

Estimated yield of the November planted lines ranged from **Finola** at 0.2 t/ha to **ECO_NEXT222** at 3.9 t/ha with the middle 50% producing 0.9 to 2.0 t/ha (median = 1.5 t/ha). Three lines (**ECO_NEXT218**, **ECO_NEXT202** and **EC1300159**) exhibited yields of ca. 2/ta and a CV below 50%. A standout in this planting window was **ECO_NEXT222** which produced the highest yield (Friedman, $p < 0.01$) and a CV below 40%. This line also had the second highest harvest index (33%) while those of **ECO_Excalibur** (28%) and **ECO_NEXT202** (28%) were also of note. Plant height was within scope for mechanical harvesting with the tallest at 1.4m and the middle 50% of lines growing from 891 to 1270 mm tall.

Table 1. Estimated yield (t/ha) for 15 lines planted on the north coast of Tasmania on the 25th November and 9th December 2016, and on the 2 January 2017.

	November Planting		December Planting		January Planting	
Cultivar	**Yield**	**sd**	**Yield**	**sd**	**Yield**	**sd**
CFX	0.3	-	0.7	0.6	0.9	0.8
ECO_CHY	2.5	1.5	2.4	2.6	2.0	2.3
CRS-1	1.0	0.8	1.4	1.9	0.5	0.3
Finola	0.2	0.1	0.2	0.2	0.1	0.1
ECO_EXCALIBUR	2.0	1.3	0.5	0.5	-	-
EC1300159	2.2	1.1	2.5	1.2	2.4	1.6
ECO_NEXT202	2.0	0.6	3.5	2.2	8.4	12.2
EC1300205	0.9	0.5	1.3	0.9	1.9	1.4
EC1300209	0.9	0.3	1.2	0.4	1.7	1.5
ECO_NEXT218	1.9	0.6	3.7	2.2	3.0	1.2
ECO_NEXT222	3.9	1.5	6.5	4.0	1.9	1.0
EC1300253	1.0	0.4	0.8	0.6	4.7	4.4
EC1300254	2.0	1.3	3.7	3.5	3.2	1.3
CRAG	0.8	0.7	1.0	0.5	0.7	0.6
ECO_CHG	-	-	-	-	0.2	0.1
Freidman statistic	P<0.001		P<0.001		P<0.001	

The yield response to planting 2 weeks later in December varied across lines (Freidman $p < 0.01$) with some noticeably increasing (**ECO_NEXT202**, **ECO_NEXT 218** and **EC1300254**) while **ECO_Excalibur** yield decreased. **Finola** again produced the lowest yield (0.2 t/ha) and the middle 50% of lines ranged from 0.9 to 3.2 t/ha (median = 1.3 t/ha), the upper range of this quantile 1.2 t/ha higher than the November planting. **ECO_NEXT222** once more produced the highest yield at 6.4 t/ha however the CV of yield in this planting slot rose to 61%. **EC1300159** was the only line with a CV of yield below the 50% threshold at 48%. **ECO_NEXT202** and **ECO_NEXT218** invested 32% of dry matter into seed production (excluding leaf material) consistent with the upper range of the harvest index of the November planting, while the middle 50% of lines invested 13 to 25% (median = 15%).

Plant height in the December planting remained consistent with the November planting for **CFX**, **ECO_EXCALIBUR**, **EC1300209**, **EC1300254** and **CRAG** and declined for the remaining cultivars. Lines **EC1300254** and **ECO_NEXT218** yielded approximately 3 t/ha with an estimated CV of yield lower than 50%. While this tonnage is comparatively high it was well exceeded by **EC1300253** (4.7 t/ha) and **ECO_NEXT202** (8.4 t/ha; CV=145%) albeit in both cases the CV of yield was very high. **ECO_CHG** and **Finola** produced the lowest yields; **Finola** due to early flowering and short stature (447±97mm) and **ECO_CHG** due not fully flowering before the end of the experiment while reaching a height of (2045±267mm). The middle 50% of cultivars in this planting window produced an estimated 0.8 to 2.9 t/ha of seed (median = 1.8 t/ha). With the exception of **ECO_CHG**, mean plant heights were shorter in this planting window. Both **Finola** and **ECO_CHG** produced little seed and hence the harvest index for these lines was less than 1%. Across the middle 50% of lines the harvest index ranged from 10 to 22% (median = 15%) while **ECO_NEXT222** had the greatest at 28%.

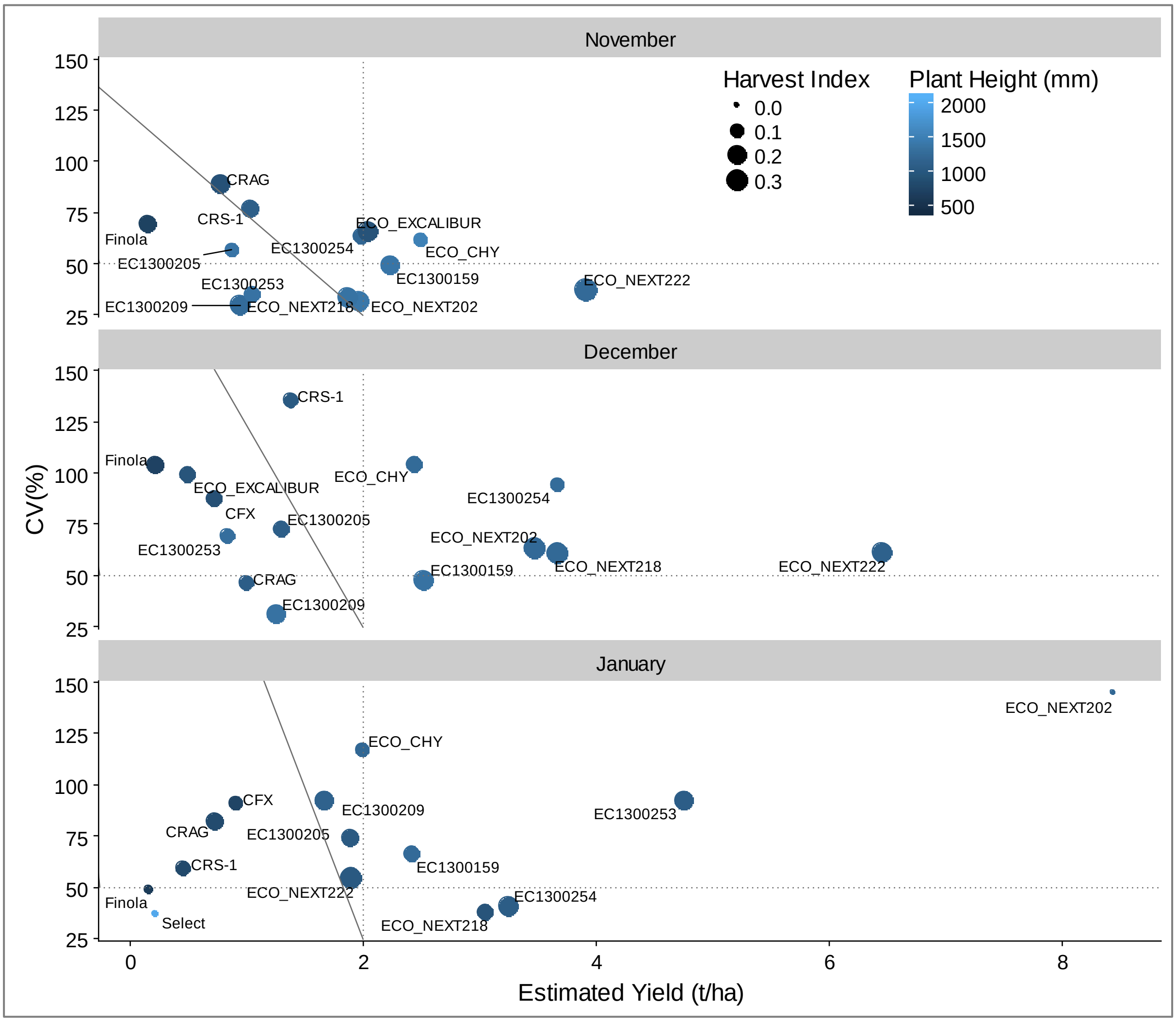

Figure 3. Mean estimated yield of 15 hemp grain plant accessions plotted against the corresponding coefficient of variation of yield for trials planted on the 11th November, 9th December and 4th January 2017. The harvest index is proportional to the marker size, and the plant height is scaled by label colour. Quadrants are defined by a breeding target of a minimum 2 t/ha and a co-efficient of variation for this attribute within each accession below 50%.

Discussion

As a relatively new crop, pursuing an increase in the gross yield of Tasmanian hemp grain crops will benefit from research into breeding, varietal adaptation studies and agronomic research. To increase gross margins competitive with other crops grown in the high-input high-output rotational cropping systems in Northern Tasmania, adaptation studies and breeding may bring about the fastest gains. This variety study has illustrated that the land races coded by Ecofibre Industries as **EC1300254**,   **ECO_NEXT218**, **ECO_NEXT202**, **EC1300159** and **ECO_NEXT222** all have significant potential to consistently provide gross yields above 2 t/ha, perhaps as high 8 t/ha in the cool temperate climate of Tasmania. This is significantly higher than that reported for recognised dual purpose varieties such as an average of 1.7 t/ha for **Finola** in Eastern Finland [7], yields in Corroy le Grand, Belgium of 1.49 t/ha from **Uso 31**, 1.75 t/ha from **Fedora 17**, and 1.56 t/ha from **Santhica 27**, 1.75 t/ha [8], and ca. 0.6 to 0.7 t/ha for **Fasamo** and **Finola** grown at Melfort, Sakatchewan, Canada

[9]. The expected average yield across Canada for grain yield in 2012 was reported to be 0.85 t/ha [10]. Apropos to yield only, **TS1300222** exhibited estimated gross yields of 3.9±1.5 in the late November and a less reliable 6.5±4 t/ha in early December and when taking both yield and stability into consideration is one of the most promising lines evaluated. In Tasmania, January is regarded as a late planting slot that allows for a second crop following an earlier planting, this slot typically filled with lucrative fresh market beans. **ECO_NEXT202** produced an exceptionally high yield in this planting window yet its high CV of yield indicates its putative estimated yield of 8.4±12.2 should be held with caution. In all, this study has illustrated there is sufficient evidence that further open pollinated selection of these promising lines will derive higher yielding varieties capable of lifting gross margins.

Historical breeding appears to have favoured fibre varieties, particularly breeding efforts over the last half century, and hence most hemp phenotypes are tall. This is problematic when adapting existing horticultural and grain production systems to hemp seed production, as most practices and machinery are adapted for crops with lesser stature. Difficulties we encountered during this study, which was situated within a commercial crop of **ECO_EXCALIBUR** included an inability to access the crop to spray or fertilise during late crop stages, as plant height exceeded the spray booms lifting capacity. Contract harvesters also reported that the height of the crop increased combine header's angle of attack to one not optimal for harvesting, and that stem toughness increased blade wear. Hence while yield is paramount, future breeding efforts and agronomic programmes also need to consider the production of low stature hemp lines, perhaps lines that are bred for grain as a sole purpose. These lines should be short in stature, have a relatively high harvest index and possibly as suggested by others highly branched [1].

Acknowledgment
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Industrial Hemp Production Trials in South Australia

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Keywords: Industrial Hemp, *Cannabis sativa*, grain, variety, sowing time, adaptability

Abstract
In conjunction with the legalization of industrial hemp growing in South Australia in 2017, a project was instigated by the state government to investigate agronomic factors important to hemp growing in the state. The project was undertaken by the South Australian Research and Development Institute (SARDI), a business unit of the Department of Primary Industries and Regions SA (PIRSA). The objective of the project was to investigate the most suitable varieties and most appropriate planting time for hemp grain production at two locations in South Australia. Trial sites were established at Loxton (lat. -34.4°) and Kybybolite (lat. -36.9°).

Each trial site contained five time-of-sowing plots, and within each plot four replicates of each of five varieties were planted. The varieties planted were selected from a wider pool of seed sourced from within Australia, which were subjected to pre-screening by the University of Adelaide (R. Burton, 2018 unpublished data). The varieties selected for planting in the field trials were ECO_PR13, Ferimon 12, Han NE, ECO_CHG and Frog 1.

Planting dates ranged from late October to mid-January, at roughly three-week intervals. Plant height and Normalised Difference Vegetation Index (NDVI) were measured weekly, and growth stage twice weekly. At grain maturity yield of grain and biomass were measured.

Preliminary results are discussed, including plant growth and development measurements, and grain and biomass yields where available.

Introduction
Industrial hemp production has previously not been possible under South Australian legislation, which classed members of the genus *Cannabis* (L.) as a prohibited plant, irrespective of the variety or the levels of Tetrahydrocannabinol (THC) in the plant.

The Industrial Hemp Act 2017 was passed by the South Australian Parliament on 16th May 2017. The act and regulations were proclaimed on 12th November 2017, making industrial hemp production legal under specific licencing and monitoring conditions. Coincidentally, Food Standards Australia and New Zealand (FSANZ) approved hemp seed as a human food, and South Australia ratified that decision on 12th November 2017.

In light of these developments, and with lobbying from the Industrial Hemp Association of South Australia, the South Australian Research and Development Institute (SARDI) was requested to conduct trials of industrial hemp production in South Australia. The decision was taken to focus the research on production of hemp grain for human food, whilst also evaluating other hemp products (hurd and bast) from the trial plantings. Industry advocates within and outside of government agreed that the most likely industry development investment in the short term would be for food end uses given the lower entry capital expenditure required, with investment in fibre processing a longer term proposition due to the larger capital expenditure required. The trials were designed to investigate the impacts of geographic/climatic location, time of sowing, variety, and interactions between these factors under a summer irrigated production system. The trials were fully replicated to ensure robust findings.

Methods
Dr Rachel Burton from the University of Adelaide conducted screening of grain composition from 20 initial varieties/advanced breeding lines of industrial hemp, from which five varieties were selected for further evaluation at two field sites. The varieties selected for inclusion in the trials are summarised in Table 1.

Two trial sites were established, on SARDI Research Centres at Kybybolite (Lat. -36.9°) and Loxton (Lat. -34.4°). At each site, Randomized Complete Block Designs (RCBDs) were laid out with Time of Sowing (ToS) as the primary blocks, with the earliest ToS at the southern end and progressing northward for subsequent ToS to minimise shading of young plants by older plantings. Actual dates of sowing for each ToS treatment at the two trial sites are shown in Table 2. Within ToS blocks, four replicates were laid out from east to west, with each of the five varieties randomly assigned within each replication.

Table 1. Summary of varieties planted in field trials.

Variety	Origin	Primary use
ECO_CHG	Australian selection	Grain & Fibre
ECO_PR13	Australian selection	Grain
Ferimon 12	French variety	Grain & Fibre
Han-NE	Chinese variety	Grain
Frog One	Australian selection	Grain & Fibre

Table 2: Actual sowing dates at each site

Time of sowing treatment	Sowing date at Loxton	Sowing date at Kybybolite
ToS1	20th October 2017	23rd October 2017
ToS2	10th November 2017	7th November 2017
ToS3	30th November 2017	29th November 2017
ToS4	20th December 2017	18th December 2017
ToS5	15th January 2018	11th January 2018

Regular monitoring at each site measured the density of plants in each treatment plot after establishment, growth in plant height, and development of plant growth stages using the decimal coding system of Mediavilla [1]. Dates of harvest were also recorded, and records kept of rainfall and irrigation applications to the plantings.

Results

Crop Establishment

Plant counts carried out between 6 and 12 true leaf stage, well after initial seedling emergence, and representing the established plant stand in each treatment plot, are shown in Figure 1. Bars represent the average of four replicates of each variety at each ToS.

It is clear from Figure 1 that establishment was lower in later ToS treatments at both sites, in spite of a consistent seeding rate within each variety across sites and ToS treatments. The reasons for this are potentially numerous. A key factor at Loxton appears to have been very hot temperatures (40°C+) during emergence in ToS 4 & 5, and the suspicion that irrigation was unable to maintain seedbed soil moisture at adequate levels during seedling emergence.

At Kybybolite suspicion falls on the irrigation water, which is quite saline (2000 ppm). In the earlier ToS treatments there was good soil moisture prior to sowing, and regular rainfall following sowing, such that the average salinity of water applied was lower than later on when irrigation water was the only source of water available. Leaf burn symptoms were seen on small plants in the later ToS treatments, including plants that appeared to be completely dead.

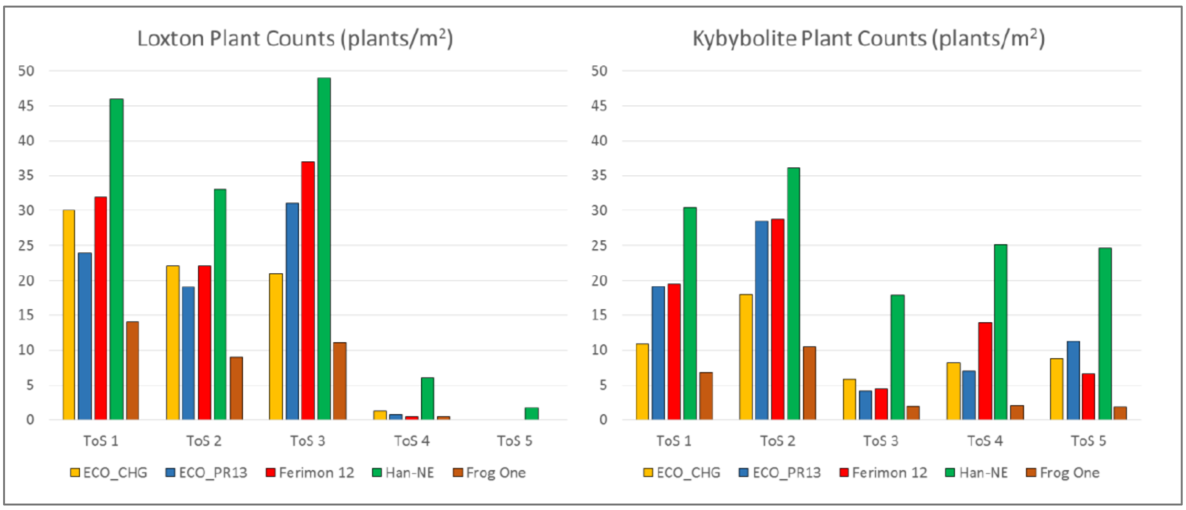

Figure 1. Average plant establishment at both trial sites.

A key consequence of the lower plant density at later ToS treatments, and the less leafy nature of some varieties (ECO_PR13 and Ferimon 12) was the development of weed problems, especially caltrop (*Tribulus terrestris* L.) at Loxton. A vigorous stand of hemp will easily outcompete most weeds, but a thin stand allows sunlight to penetrate to the weed seedlings. This weed problem poses clear issues for harvest of hemp seed, especially in the presence of weeds such as caltrop. Plant densities as low as 20 plants/m2 outcompeted weeds in the leafy varieties at Loxton, but weed problems were still present in ECO_PR13 and Ferimon 12 at the highest plant densities achieved in these trials (35 plants/m^2).

Plant Growth and Development

Average crop height across the four replicates of each variety in ToS 1 are shown in Figure 2. The data reflects the development of two distinct plant forms at these sites. Note that at Kybybolite the growth curve is flatter in the initial period, reflecting a delay in establishment and growth due to cooler conditions at this site than at Loxton.

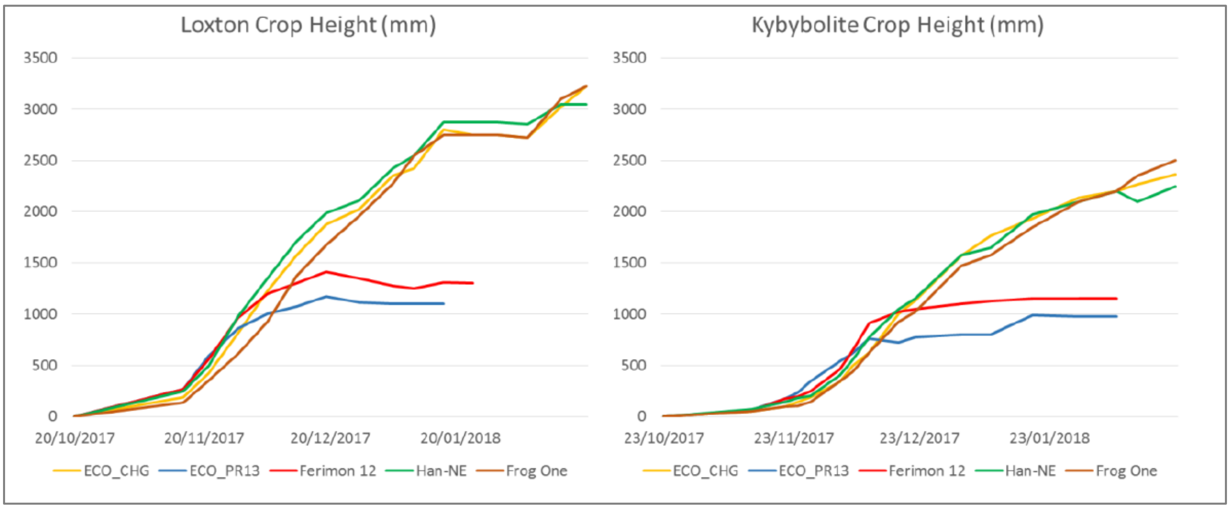

Figure 2. Average plant height at ToS1 at both sites.

ECO_CHG, Han-NE and Frog One developed large, leafy plants which branched readily and continued to grow until they reached a height of around 3 m in the earliest ToS treatments at Loxton. On the other hand, ECO_PR13 and Ferimon 12 developed less leafy, non-branching plants which stopped growing much earlier in the early ToS treatments.

The reason for this is that these two varieties flowered much earlier than the other three. Figure 3 shows the number of days from sowing to the emergence of female flowers. Ferimon 12 is not included in the graph as the decimal system used doesn't differentiate between male and female flowers in monoecious varieties. The pale bars represent variety/ToS combinations which have not flowered to date.

The graphs demonstrate that ECO_PR13 flowered at around 25 days after sowing at Loxton, and around 35 days after sowing at Kybybolite, irrespective of time of sowing (with the exception of ToS 4 & 5 at Kybybolite which have not yet flowered despite being over 35 days old). Han-NE on the other hand shows much greater variability in days from sowing to flowering, but close agreement in actual date of flowering irrespective of the date of sowing, such that female flower emergence has occurred from the beginning of February at both sites in this variety. In turn, ECO_CHG is about to commence flowering at both sites, and Frog One is still some way from flowering.

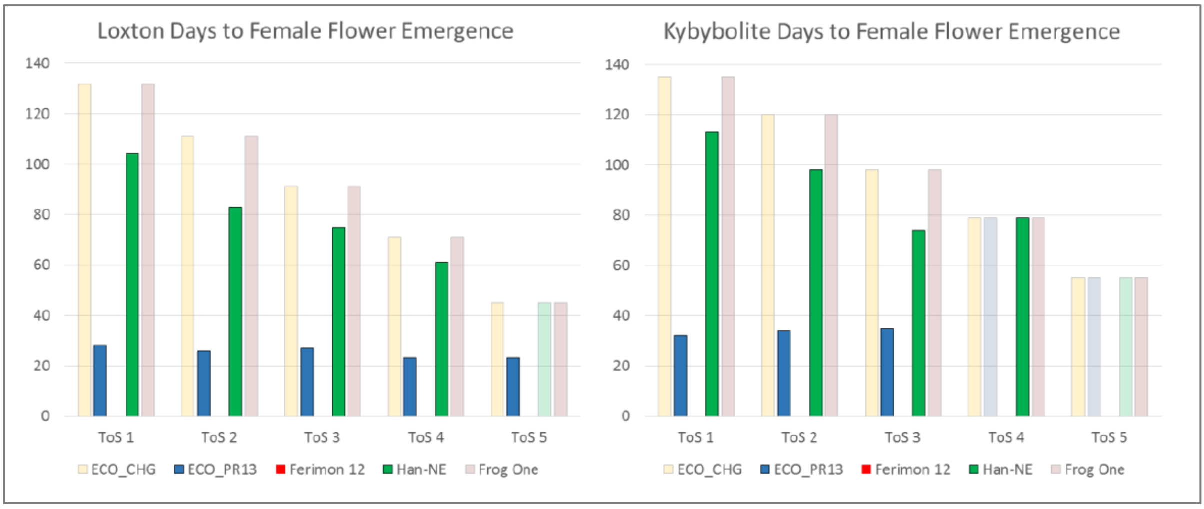

Figure 3. Average days from sowing to female flower emergence at both sites.

In this respect ECO_PR13 and Ferimon 12 behave as day length neutral plants, flowering when they reach a certain growth stage or plant height without reference to the stage of the season. As such they appear to be much less sensitive to the impact of ToS. These two varieties originated in higher latitudes, and short growing season at these latitudes favours early flowering regardless of biomass (pers. comm. O. Ansari, 2018).

The other three varieties behave more as day length sensitive varieties, appearing to wait for appropriate day length signal before flowering, irrespective of time of planting or biomass accumulation, based on the pattern of plant height and flowering date across the ToS treatments (data not shown). As a result they are much more affected by sowing date, especially in terms of plant growth prior to flowering. The 3 m tall plants of these varieties in the early ToS treatments at Loxton are less suited to machine harvesting than plants of ECO_PR13 and Ferimon 12.

Growing Cycle

Figure 4 displays the average time from sowing to harvest for each variety across ToS treatments and trial sites. Pale bars represent the time to date since sowing for treatments that have not yet reached harvest. The corresponding ToS treatments of ECO_PR13 and Ferimon 12 reached harvest earlier at Loxton than at Kybybolite, reflecting generally cooler conditions at Kybybolite. Note that although some treatments have been harvested, the grain has not been threshed from the plants, and no yield data is available as yet.

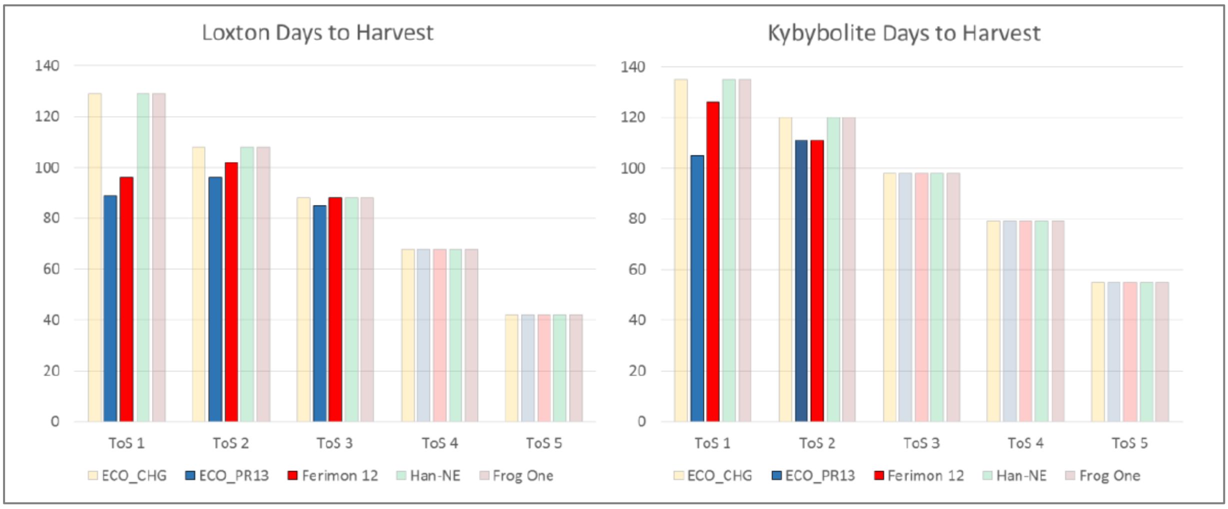

Figure 4. Average days from sowing to harvest at both sites.

Taken over the full period from sowing to harvest, the sum of all rainfall and irrigation applied during this period per treatment is shown in Figure 5. Pale bars represent the water applied to date in treatments which have not yet been harvested.

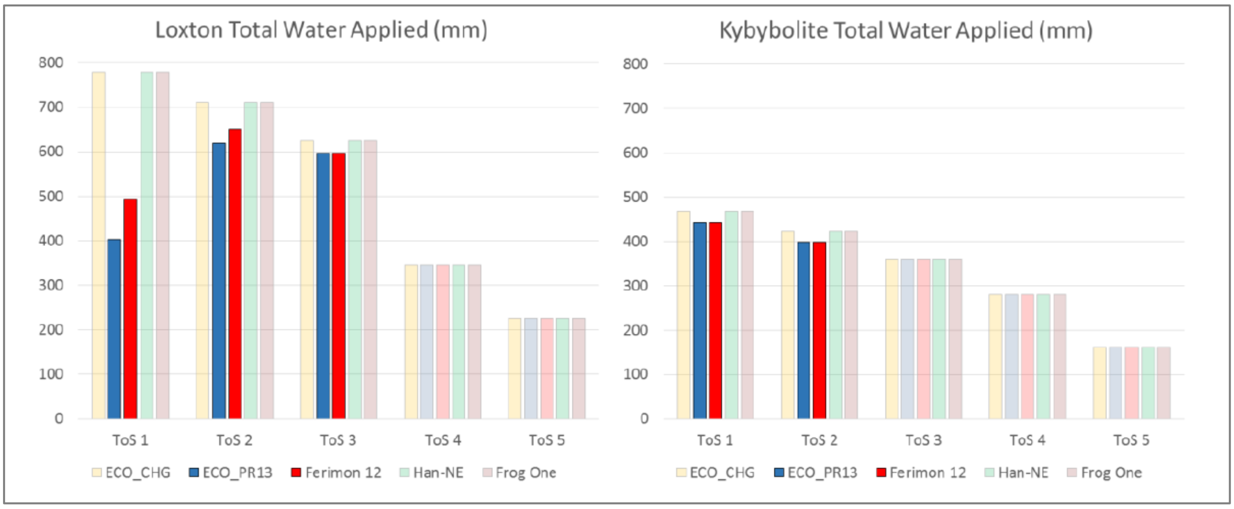

Figure 5. Total water applied at both sites.

Although the treatments at Kybybolite took longer to reach harvest, they used less water, due to the higher latitude and cooler, more humid climate at this site. However, the irrigation at the two sites is managed by different staff, and applied with quite different irrigation systems, so direct comparison is difficult. However, we can conclude that total seasonal water use for the varieties ECO_PR13 and Ferimon 12 is likely to be around the range of 400 to 600 mm, or 4 to 6 ML/ha, across the likely growing region.

Note that the water applied to the early ToS treatments of varieties ECO_CHG, Han-NE and Frog One will be substantially greater than these numbers, as these treatments are only just flowering, or haven't even commenced flowering. Later ToS treatments may have substantially lower total water use figures.

Conclusion

In the absence of yield data, it is premature to make recommendations about the suitability of different varieties or sowing dates for industrial hemp production in South Australia. However, some preliminary observations are possible. There are clear differences in the behaviour of the varieties trialled at these sites. ECO_PR13 and Ferimon 12 show no sensitivity to day length, and as a result the time of sowing is expected to be less critical than in the other three varieties which are strongly day length sensitive. However, plant establishment was problematic in the later ToS treatments. Sowing seed after early December, during the peak of summer heat, is not recommended on the basis of this research. Problems with maintaining seed-bed moisture levels and issues with salt burn in this period worked against good plant establishment. Salinity issues may be moderated through the use of drop tubes (centre pivot and lateral move irrigators) or drip irrigation, to avoid or minimise leaf wetting and the resultant foliar uptake of salts.

Establishment of dense stands of hemp plants is vital to good weed control. The very narrow range of herbicides approved for use on hemp makes chemical weed control problematic, and smothering weeds with hemp plants is a much better option. Good control of caltrop was achieved at Loxton at plant densities around 40 to 50 plants/m2 in ECO-CHG, Han-NE and Frog One, but higher plant density should be the aim in the less leafy varieties ECO-PR13 and Ferimon 12.

Acknowledgements
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We also wish to thank the Project Steering Committee for their input in ratifying trial objectives and selection of varieties and TOS treatments. The committee comprised Ruth Trigg (Industrial Hemp Association of SA), Matthew Rowland (Cannabis Council of SA), Wade Dabinet (Grain Producers of SA), Stuart Gordon (CSIRO), Martyn England (Department of State Development), Dave Lewis (PIRSA) and Peter Appleford (SARDI).

Thanks also to Rachel Burton of the University of Adelaide and Stuart Gordon of CSIRO for their contributions to the project.

Finally, thanks to the team from SARDI who continue to assist with the trial sowing operations and ongoing management of the trial sites, particularly Mickey Wang, Gary Grigson, Brian Dzoma and Peter Telfer who assisted with activities at Loxton, and Ian Ludwig, Amanda Pearce and David Robertson at the Kybybolite site.

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The Australian dual purpose low thc variety *Frog One* – Performance in temperate and subtropical zones and research in tropical environments[1]

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Keywords: Hemp seed, farming, dual purpose

Abstract

The development of the Australian hemp industry has been limited not only by regulation but also by availability of suitable seed for farming. Development of varieties stalled in those parts of the world affected by prohibition and in many cases such as in the USA, the result was the loss of good varieties such as those developed in the state of Kentucky which prior to prohibition had a flourishing grain industry.

Australia's southern states are reasonably well suited to farming hemp with European varieties (many of which are from similar latitudes to Tasmania) and there are a quite a wide variety of cultivars available, however certainly as far as fibre farming goes, these varieties do not produce anywhere near comparable biomass to varieties that have been bred for Australian conditions which commonly reach 4 – 5 m in height. They tend to revert to flowering before they gain significant height producing low fibre yields. Between northern Victoria and northern NSW, greater successes have been had with European varieties for grain production, when they are planted early enough.

As early as 1999 European plant breeders had identified that temperate to tropical climates such as Australia had the ideal climate to develop a very late flowering high yielding variety. *Frog One* was developed as a dual purpose variety from new genetic material through hybridization of 12 landraces in a breeding program conducted in southern NSW between 1997 and 2000 and *Frog One syn 'Xulan'* was the first variety of its type to be granted PBR in Australia in 2008.

It is a dioecious variety developed for production of both seed and fibre and it can be continuously cropped for fibre from August/Sept through to February/March and planted for grain in mid-Feb/March for harvest in June/July. These planting windows are far greater than those available with European varieties.

The variety is ideal for sowing after a wheat crop, presenting another cropping opportunity to farmers, when no other seed crop is feasible for that window of sowing, creating the opportunity for extra income for that cropping time or cycle/ha.

Since 2008, *Frog One* has demonstrated its vigour in fibre and grain production in multiple dry land and irrigated locations and while the majority of crops have been in New South Wales, it has been farmed as far north as Cairns and down to south-western Victoria for fibre and on multiple sites from southern Queensland to south-western Victoria for grain, including in the Riverina and on the NSW Tablelands.

[1] Klara Marosszeky was a late apology from the Conference Program.

Thursday, 1 March 2018

SESSION 5
Lessons in crop production and on-farm processing

Chair: David Williams, Director, Robinson Centre for Appalachian Resource Sustainability (RCARS), University of Kentucky USA

Results from a study conducted in 1995/96 on hemp for fibre in SE South Australia
Trent Potter, Yeruga Crop Research, SA

Lessons learnt from several years as a hemp agronomist on the East Coast of Australia – from Tasmania to Emerald, QLD
John Muir, Hemp Farming Systems Consultancy Group, QLD

Challenges cultivating selected hemp varieties of Cannabis sativa on exhausted phosphate mine sites in a tropical environment: the case study of Christmas Island
Luca DePrato, Murdoch University, WA

Hemp production in Malawi with focus on harvesting date, retting process and fibre content
Stephanie Schloegel, Ecofibre Australia, QLD

On-farm decortication
Charles Kovess, TCI, VIC

Worker health and wellbeing during cultivation and processing of hemp'
Maggie Davidson, Univ. Western Sydney, NSW

Results from a study conducted in 1995/96 on hemp for fibre in the South East of South Australia

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Keywords: Fibre production, time of sowing, irrigation,

Abstract

In the early to mid-1990s there was significant interest in the development of hemp as a source of fibre and trials were established to investigate varieties and the agronomy of hemp production. At Kybybolite Research Centre in the South East of South Australia, five commercial French varieties of hemp were sown over a range of sowing dates under irrigation, starting in winter on June 2 1995. Plot size was 8 rows at 18cm row spacing by 10 m long and 4 replicates were used. The experimental design was a split plot with time of sowing as main plots and varieties as subplots. Irrigation at about 25 mm per week was applied by a travelling irrigator. Sowing hemp before September was unsuccessful because the plants flowered early and produced little dry matter. These plots were therefore abandoned. Sowings during October and November produced substantially more growth because plants had a longer period from emergence until the start of flowering. Highest dry matter production occurred with October and November sown hemp with the variety Futura 77 producing 9-10 t/ha. In order to produce higher levels of plant biomass it may be necessary to grow varieties that flower even later than Futura 77.

Introduction

In 1991 the Tasmanian Government was the first Australian state to grant a research licence enabling evaluation of the agronomic and market potential of a viable industrial hemp industry. Industrial hemp research has been conducted in South Australia, Tasmania, Victoria and New South Wales. In SA, research was undertaken in 1995 to determine the agronomic potential as well as the processing and market potential of industrial hemp. To enable the potential of industrial hemp under SA conditions to be evaluated a research licence has been issued under Section 56 of the Act to the Yorke Regional Development Board with the research being conducted by South Australian Research and Development Institute and IAMA Technical Services. The trials were conducted under stringent security conditions and in accordance with an agreed trial protocol.

Materials and Methods

Three trials were sown, two by SARDI, at Turretfield Research Centre in the lower North and at Kybybolite in the South East and one by IAMA at Arthurton on Yorke Peninsula. Five French hemp varieties were to be sown at six weekly intervals between May and October. All trials were grown under dryland conditions except for Kybybolite where the hemp was irrigated. The trials at Arthurton and Turretfield were unsuccessful as June and July sowings flowered too early and produced negligible plant growth and sowings in October did not emerge due to dry soil conditions.

At Kybybolite five commercial French varieties of hemp were sown over a range of sowing dates. The site had been prepared before winter and 2.5 t/ha of lime had been incorporated to raise the soil pH to about 6. Plot size was 8 rows at 18cm row spacing by 10 m long and 4 replicates were used. Buffer plots were sown on either side of each time of sowing block. The experimental design was a split plot with time of sowing as main plots and varieties as subplots. Sowing rate was adjusted for seed size and germination percent and seed was sown about 2 cm deep. At sowing DAP at 144 kg/ha was applied and after emergence additional nitrogen at 50 kg/ha was top-dressed as urea on all plots. Irrigation at about 25 mm per week was applied by a travelling irrigator, higher water application rates could not be used because the different times of sowing meant that small seedlings were often present. Plant emergence was similar for all varieties with about 200 plants/m2 being achieved.

At harvest, the outside 2 rows on either side of the plot were discarded and the inside 4 rows were cut at ground level and weighed. A subsample of 1 kg was kept, and oven dried to determine dry weight.

Results and Discussion
The trials have confirmed that industrial hemp is a short day plant suited to spring sowing. Attempts to sow the crop in winter were unsuccessful as plants grew to only about 30 cm high before flowering. These sowings occurred in 2 June and 10 July and conditions during winter were very wet. Plants flowered during September and early October and these sowings were destroyed.

Table 1. Total production (t/ha) of dry matter by 5 hemp varieties sown at 5 dates at Kybybolite.

Sowing date (1995)	Futura 77	Ferimon	Fedrina 74	Fedora 19	Felina 34
11th September	5.2	3.6	4.2	3.5	3.9
5th October	9.9	5.2	8.2	6.3	6.5
15th November	8.9	4.9	6.1	6.8	6.7
4th December	4.8	3.7	4.7	4.3	3.6
11th December	5.5	3.4	4.2	3.5	4.1
Mean	**6.9**	**4.2**	**5.5**	**4.9**	**4.9**

lsd (0.05) for comparisons of variety means within a time of sowing, 1.3
lsd (0.05) for comparisons of variety means between times of sowing, 2.0

The crop appeared to be best adapted to either irrigated areas or areas where summer crops are traditionally grown. Under irrigation, mid to late spring plantings gave the best growth. Results from Kybybolite showed that total dry matter yields of October and November sown hemp ranged from 9-10 t/ha for the variety Futura 77 down to 5 t/ha for the variety Ferimon. The other varieties produced intermediate biomass yields. Futura 77 produced the highest biomass yields at all harvests and appeared the best suited variety of the five under test. Sowings during October and November produced substantially more growth because plants had a longer period until the start of flowering although flowering generally began between 6 and 7 weeks after sowing. Hemp sown after November and before October grew poorly so that the optimum sowing date appears to be during October and November. The 10 t/ha produced in this trial compares quite favourably with yields obtained elsewhere in Australia. The only areas in SA where industrial hemp may warrant further evaluation as a dryland crop are in the mid and lower South East where spring sown, dryland crops are traditionally grown in some years when spring rainfall may be above average and soils can store adequate moisture.

In order to produce greater biomass than achieved in this experiment it may be necessary to grow varieties that flower even later than Futura 77. Similar results have been found in Tasmania (S. Lisson-pers.comm.).

Plant populations of approximately 200 plants/m^2 were established and weeds presented few problems in hemp production when sowings occurred in October and November. Hemp growth was rapid and smothered weeds to produce a relatively weed free stand. However, in earlier sowings, weeds competed with hemp. Grasses were killed with normal grass herbicides with no evidence of damage to the hemp plants, however broadleaf weeds could not be controlled. If lesser plant populations were to be established it may be expected that weed control would need to be better managed by rotation, time of sowing and the registration and application of appropriate herbicides.

Insect pests were not noted to have an effect on hemp growth except for Lucerne flea (*Sminthurus viridis* L.), which required control in early sowings at all sites, while later sowings at Kybybolite were unaffected.

Soil conditions appeared to have little effect on plant emergence at Kybybolite. Likewise overhead watering also seemed to be adequate for plant growth, although due to the trial design with randomised times of sowing, the amount of water that could be applied early was constrained often by having small plants newly emerged and we were careful not to apply too much water at that growth stage. In Victoria, plant growth was reported to be severely reduced by waterlogging in irrigation bays (D. Pye, pers-comm.) and therefore waterlogging could be a severe impediment to hemp production in some years. In the trial at Kybybolite the plants were grown with similar nutrient inputs to a well grown canola crop, however no nutrition trials were conducted so perhaps yields could have been further increased with higher inputs. Plants were not to be allowed to set seed in the South Australian trials so that seed yield could not be estimated.

The Yorke Regional Development Board (Graham, 1995) conducted a feasibility study on end-use and market potential and identified the high cost of processing equipment as the main limiting factor. They concluded that an industrial hemp industry for fibre alone in the medium term would not be viable as hemp products would not be competitive against products made from other fibres eg wood or cotton.

Conclusion

In South Australia, hemp is only likely to be successful agronomically as an irrigated crop. The best production achieved at Kybybolite was 10 t/ha for Futura 77 sown between October and November. Further studies could be undertaken to assess other genotypes, particularly genotypes that took longer from sowing to flowering to enable more biomass to be produced, or genotypes that could be used for end uses other than fibre production. Any future research and development should focus these types but also on post farm gate processing and developing better agronomic packages for particular end uses.

Acknowledgements

Field work was conducted by Jack Kay, Ian Ludwig, Robert Stacey and Matthew Hoskings.

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Lessons Learnt from several years as a Hemp Agronomist on the East Coast Australia – from Tasmania to Emerald QLD

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Keywords: Regional production practices; breeding, new cultivars and THC testing; crop care including water, nutrient, weed and pest management regimes; harvesting and early-stage processing; grain storage, processing and products

Abstract
My fortunate association with hemp in Australia has been over the last ten years, as a hands-on, infield hemp agronomist, both for EIO and as a consultant. I came to an understanding with this crop through continuous improvement and innovation. And with an action learning process about the plant, as an alternative potential grain and fibre crop for Australian farmers to consider and experiment with. It was a steep learning curve, but one of great interest and opportunity for all involved. I would like to share some of those lessons learnt.

Firstly, despite all the hype and misinformation that is often published about hemp, if only half is true, it certainly is still the one plant to take to the moon to grow and use. So I want to dispel some of the rumours and non-facts that exist out there first, for profitable hemp production:

- Hemp is NOT a NO input, easy crop that once planted, you sit back & watch it grow.
- Hemp is not just for anyone to grow, as needs certain conditions and requirements.
- Hemp can be organic, but this doesn't mean it has no pests or diseases to contend with.
- Hemp can be a multipurpose fibre and grain crop, but this means accepting a compromise on one or the other product outputs, in terms of quantity or quality.
- Hemp cannot be grown just anywhere, as is very site specific, due to differing varieties, sowing dates, flowering dates and latitude, which all determine its final height and potential products outputs and quality.

On the other hand, this great diversity in its genetic makeup and varietal differences, will allow hemp to be one of the latest and most flexible rotational crops suitable to many different and varied geographical farming locations around Australia. Especially mainly, on well drained irrigation farms, so as to reduce crop failure risk, until we can wrap our head around where this crop best fits in here! This flexibility will include many various sowing date possibility, which can be from early spring, to late summer/early autumn plantings, especially in above the sub tropics. This will also allow farmers to be adaptive and responsive to increasing changes in rainfall and climate patters in the future, and hence enable sowing of suitable varieties, when soil moisture is adequate, and not having to wait, when full soil profile moisture fallow exists. This is a true opportunistic, rain-fed or dryland crop – suitable for Australian agricultural practices.

This pictorial presentation will take you through my journey of learning over the last ten years, and share the highs and lows of many hemp farming lessons learnt the hard way, with growers, so we can all reflect and share from this, and hopefully not repeat the same mistakes again, so we can all contribute to a new vibrant hemp industry into the future.

Challenges cultivating selected hemp varieties of *Cannabis sativa* L. on exhausted phosphate mine sites in a tropical environment: The case study of Christmas Island

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Keywords: Ecofibre, *Cannabis sativa*, tropics, variety, soil compaction

Abstract

Legalization of industrial hemp for food and medical application has renewed the interest in this well-known and historical crop across Australia, including its territories. An opportunity to explore industrial hemp cultivation arose on a phosphate mining lease on Christmas Island (CI), located in the Indian Ocean at a latitude of 10°S. The objective of this study was to assess the response of three varieties of industrial hemp, provided by Ecofibre, to diverse sites and soil conditions. The challenges of cultivating hemp on mining land were hypothesized to be sub-optimal soil structure and low soil organic matter. These factors combined to decrease the ability of hemp to develop its full biomass potential. To investigate these issues, four trials were established comparing three dioecious varieties (ECO_CHG, ECO_CHY and ECO_MS77) under various conditions (two nursery soil trials and two field sites). Plant height, days till flowering, and other phenological characteristics were measured to compare the response of the varieties to the local tropical environment.

Introduction

The establishment of a healthy root system is necessary for survival and growth of a well-developed plant. The root system is the plant organ that allows the absorption of water and inorganic nutrients, support of the canopy, storage of nutrients and facilitates vegetative development [1]. Causes of failure of normal root growth include soil compaction, which can result from a number of factors including mechanical stress and heavy rainfall [17]. Organic matter and earthworms have been recognized as factors that can mitigate soil compaction [8] but extensive use of the soil, with heavy machinery associated with mining, can reduce earthworm populations [6]. Developing sites that have been exploited for mining for other purposes, such as agriculture, involves improving the soil structure and recreating the microbial population. Organic matter in the soil is necessary for structure and establishment of plant roots and mineralization processes that contribute to the nutritional fertility of the soil for the plant growth [16]. A selected series of crops in rotation could improve soil structure, fix nitrogen (Leguminosae) [9], extract mineral toxicity (hyper-accumulator) [7], increase the soil fauna [9], and increase soil carbon. An opportunity to investigate agriculture following mining activities arose on Christmas Island (CI), an active phosphate mine site. Previous research undertaken on CI has shown how improved soil nutrients on mined soil can increase plant biomass [14].

Various agronomical studies have shown that industrial hemp *(Cannabis sativa L.)* prefers a fresh, draining, fine soil with low levels of compaction, rich in nutrients, with structure and soil microbes [5] [3]. *Cannabis sativa* has been proven to have a strong penetrating root system that can reach more than one meter of depth [4], but presents with various problems with compacted substrate that can lead to growth stress and development of a 'L' shaped taproot [3]. It is critical to understand how the root system of *C. sativa* can develop under different soil conditions. It is well known that adding organic matter during soil cultivation in poorly structured soil improves the quality and nutrient utilization for the plants [16]. This is fundamental, especially in tropical conditions where heavy rainfall tends to increase soil compaction [13]. There is a paucity of information regarding the impact of soil structure and fauna on the development of *C. sativa* and how the root system responds to different substrates. To address this, a series of agronomic trials were undertaken on hemp on old mine sites on CI, and the preliminary results are discussed here. The trials were conducted on sites utilized for research and broad acre agricultural trials by the MINTOPE (Mining to Plant Enterprise) research group, based at Murdoch University. In this, and other sites across CI, a transition from mining to agriculture has been investigated using several research trials with various crops. Results from previous legume and grain crop trials [15] [14] conducted on CI have identified poor soil nutrition and structure as some of the most limiting factors for plant growth. *Cannabis sativa* is a short day annual plant with a vegetative and a flowering stages with particular flowering dynamics, where seeds maturation occurs at the end of the cycle [11] [2]. Therefore, responses such as flowering time and biomass, by the different varieties are important variables to investigate for the production of a range of products. The aim of the current study was to investigate the effect of soil structure, substrate and nutrition on the growth of three selected varieties of industrial hemp, developed by Ecofibre Industries.

Methodology

Study sites

Christmas Island has an oceanic tropical climate with an annual average temperature of 25°C during the day and 23°C at night. It has a total mean annual rainfall of 2199.4 mm (mean rainfall between 1973 and 2018, BOM records - station 200790), mostly concentrated over the wet season (November to March). The trial was conducted between November to April, with monthly rainfall varying between 166.6 mm to 343.3 mm with an average temperature varying between 28°C and 22°C. Two sites were selected, Airport 4 (A4) and Airport 2 (A2), part of the leased land of Phosphate Resources Limited. The sites have been used by the MINTOPE project [9] for previous trials to research the cultivation of crops such as legumes (e.g. *Lab; Arachis hypogea*) and cereals, e.g. *Sorghum bicolor* [13]. Airport 4 represents one the highest quality soils available, whilst A2 is the lowest. During the trial period, supplementary irrigation was not necessary, as 1554 mm of rainfall was recorded at the field sites.

Biological material

The hemp varieties trialed were two subtropical varieties, ECO_CHG and ECO_MS77, and a higher latitude variety, ECO_CHY. These were chosen to observe the phenological differences in growth habit, height, vigour and biomass and seed production.

Experimental design

Trial 1: growth and development on mulch (+M) vs nil mulch (– M) treatments

The experiment investigated the effect of soil amelioration through the addition of a forest mulch soil preparation mixed into the upper 25 cm of soil, and it was replicated at two locations, A4 is an agricultural site established from cleared forest, and A2 is a restored mine pit. At both sites, two treatments (9 m^2 each) were established for three hemp varieties, and three randomized replicate 1 m^2 plots for each variety. One treatment included the addition of a local forest mulch (+M), prepared and composted on the island, and added to the soil and mixed thoroughly with a rotary hoe. The second treatment was a control that was not amended with the forest mulch (-M). Both treatments had 300 g/m^2 of broad spectrum fertilizer added, containing 5/6 month slow release nitrogen (N), trace elements and added microbes (Troforte Native M 14:1: 6 NPK – Langley Fertilizers). In addition, 250 g/m2 of Ferrous Sulphate was added during soil preparation to seedlings of the three hemp varieties. Seedlings were transplanted into the field sites at a density of 12 plants per m^2 with 3 rows of 4 plants each at a 25cm by 25cm spacing.

Trial 2: Pot trial with potting mix vs CI soil

A pot trial with two different soil treatments was established in a nursery to compare plant growth and phenology, and to link with the field trial. Thirty six, 10 L (250 mm diameter) free-draining pots were used with six replicates for each of the three hemp varieties in two soil treatments. The two treatments were a potting mix (P) and the other a 1:1 (v:v) mix between potting mix and Christmas Island soil (mix CI) from site A4. Each pot was supplied with 100 grams of a broad spectrum fertilizer added, containing 5/6 month slow release nitrogen (N), trace elements and added microbes (Troforte Native M 14:1: 6 NPK – Langley Fertilizers). Soil pH corrections were needed for the mix CI as pH readings were around 8 to 8.5. The pH was corrected using two applications of 10 gr each per pot of Ferrous Sulphate (Fe: 19.5% S: 11.0%). Three seedlings were grown in each pot and hand watered once daily to saturation for the duration of the trial.

Soil preparation for field experiments

The soil at A2 and A4 was first treated to eliminate weeds with a glyphosate-based herbicide (Gladiator® Herbicide, active constituent: 450 g/L Glyphosate) at the manufacturer's recommended rate (rate: 8mL/L water). After a few days, soil was ripped with a disk plough followed by chisel plough to a depth of 40 cm immediately after a 100 mm rainfall event, allowing a deep worked soil penetration. Both treatment types were then prepared with a rotary hoe, and, for the +M treatment, a 30 cm layer of forest mulch was applied to each replicate and rotary hoed into the soil at a depth of 25 cm. This material was chosen in order to improve soil structure and to create a better growing environment for the hemp varieties. At the same time, a broad spectrum fertilizer plus trace elements with 5/6 month slow release N (Troforte Native M 14: 1: 6 NPK – Langley Fertilizers) was added to both soil treatments and mixed into the soil.

Seed sowing and seedling transplanting
A total of 1280 seeds of each of the three hemp varieties were sown into 128 cell seedling trays, with one seed per cell on the 14th of November 2017. The time of sowing at the beginning of November was chosen to schedule the growing period with the longest days of the year, in order to maximize the vegetative stage of the plants. All trays were watered by hand to saturation and monitored daily. The first seeds germinated within three days. Once the seedlings reached approximately 8 cm high, they were transplanted into pots on the 2nd of December 2017, and, for the field trial, planted into sites A4 and A2 on the 1st and 5th of December, respectively. Once transplanted, seedlings were immediately hand watered to ensure adherence of soil particles to the seedling root ball as suggested by Amaducci [3].

Growth development and day length
Phenological data were collected weekly from one week after planting. Hemp is a short-day length species so flowering follows environmental triggers. Each plant was monitored for height, health and days until flowering. Plants of each of the field trial sites (A2 and A4) and pots were observed and catalogued with a numeric code developed by Mediavilla V. [10] for growth and sex expression. Once 50% of the plants for each replicate were flowering, data were recorded and used to understand how day length affects plant growth development and physiology in the tropics (10°S).

Statistical analysis
All growth variables were descriptively analyzed through R statics software (R Core Team, 2017).

Results and discussion
Growth and development in mulch (M) vs nil (N) treatments
Two weeks after transplanting, plant growth was higher in the mulch treatment (M) characterized by better establishment, health and survival. Thereafter, the N treatment started to show a higher response in growth and health. After nine weeks growth (~seven weeks after transplanting) the height results showed that plants of ECO_MS77 and ECO_CHY on the N treatment were greater of those in the M treatment while ECO_CHG were similar between the two treatments (Figure 1). Forest mulch improved plant establishment but, perhaps, reduced the amount of nutrients in the soil available to the plants which grew slower in the M treatment. There was no difference between the two treatments, for days till flowering; more than 50% ECO_CHY plants were flowering at 20 days after sowing while ECO_CHG and ECO_MS77 started showing the first flowers formation after 11 weeks (around 80 days after sowing), that allowed for the formation of taller plants with a greater biomass.

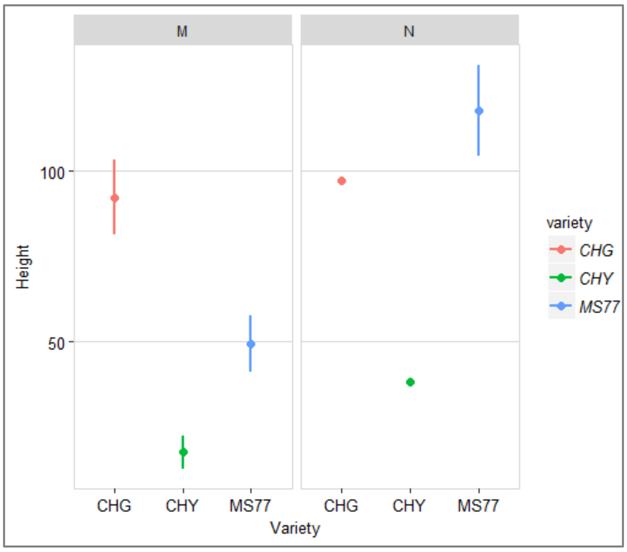

Figure 1. Height (cm) of plants of three hemp varieties (CHG, CHY, MS77) for treatments M (mulch) and N (nil) after 9 weeks, grown in phosphate mine site A4 on Christmas Island. Values are means of measurement of all the replicas after 9 weeks from sowing, with confidence intervals.

Growth and development at sites A4 vs A2

There were marked differences in growth between the two field sites, with small heights recorded at site A2 (mined soil) compared to site A4 (agricultural soil) (Fig 2). This poor growth could be related to low nutrient and soil carbon levels, as well as, potentially, low microbial activity in the A2 soil. In this trial it has been more difficult to compare the days to flowering. Between the two sites no difference was found for days till flowering for ECO_CHY plants - these were flowering 20 days after sowing. ECO_CHG plants growing at A4 started flowering after 11 weeks (around 80 days after sowing) while at A2 the same variety was not flowering. It was difficult to compare ECO_MS77 at the two sites, as the plants in A2 were struggling and not flowering, meanwhile, the same variety at A4 started showing the first flower formation after 11 weeks (around 80 days after sowing).

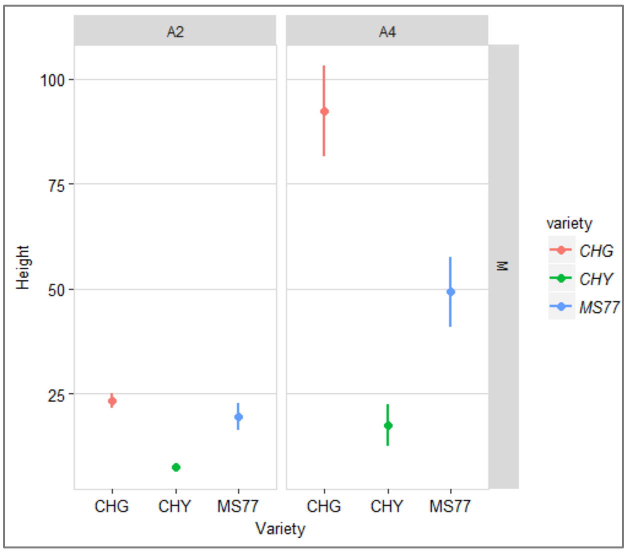

Figure 2. Height (cm) of plants of three hemp varieties (CHG, CHY, MS77) after 9 weeks growing at sites A4 and A2 on Christmas Island on treatment M (mulch). Values are means of measurement of all the replicas after 9 weeks from sowing, with confidence intervals.

Growth and development of plants grown in pots:

The seedlings grown in the potting mix (mix P), established well and grew fast in comparison to the pots containing a 1:1 mixture of CI soil and potting mix (mix CI). Plants grown in mix CI showed nutrient deficiency symptoms and leaf necrosis, and numerous seedlings died. Overall, seedlings showed a fast and healthy growth in mix P for the first 3-4 weeks, while seedlings in the mix CI soil struggled. The total number of the mix CI plants surviving was lower but at nine weeks the heights between the surviving plants was similar to the plants in the mix P soil (Figure 3). This may be due to the limited volume of soil available in the pots to sustain growth in the mix P treatment. In particular, ECO_MS77 grew poorly in the mix CI soil and no seedlings survived to week 9.

The general health of seedlings in the mix P soil was higher than those in the mix CI soil, even if the height of the plants were similar. Plants grown in the mix CI soil were nutrient deficient compared to plants in the mix P treatment (Figures 3, 4 and 5). There were no differences for days till flowering between plants grown in the pots vs A4 site or between different treatments. ECO_CHY was flowering already when seedlings were transplanted (around 20 days from sowing); ECO_CHG and ECO_MS77 started flowering after 11 weeks (around 80 days) but no differences were noted between the two soil treatments.

Figures 3, 4 and 5. (3) ECO_CHG variety in the mix P treatment showing some healthy individuals. (4) ECO_CHG variety, 2 weeks after transplanting, in the CI mix showing yellowing leaves, perhaps indicating iron deficiency. (5) ECO_CHG variety grown in CI treatment, 9 weeks after transplanting showing some yellowing, which could indicate micro elements deficiencies. Pots used for this trial were 10 L with a 250 mm diameter.

Nutritional and physiological difference between varieties

Soil preparation and adequate nutrition is essential for healthy plant development. This was observed for plants grown in the mix CI soil and at the A2 site, which had limited growth and exhibited nutrient deficiency symptoms and necrosis (Figures 4 and 5). Symptoms seemed to be iron deficiency (Figure 4) and this could limit absorption of sugars essential for photosynthesis and nitrogen uptake and consequently plant growth and yield results [12]. These challenges, if not leading to early death of seedlings, could affected the efficiency of photosynthesis. Further trials, investigating iron requirements in hemp, will need to be undertaken in post-phosphate mining substrates.

One of the varieties (ECO_CHY) was found to be not suitable for CI where day length ranges between a minimum of 11 h 30 mins in June to 12 h 44 mins in December. Consequently, the plants had limited growth with continuous flowering and seed maturity. In contrast, the other two varieties (ECO_CHG and ECO_MS77) had a longer vegetative stage and developed into vigorous and taller plants. When the first flowers started to appear, around 11 weeks after sowing, plants were on average 122 cm and 98 cm for ECO_MS77 and ECO_CHG, respectively and y. This growth indicates that both varieties have the potential to be grown on Christmas Island.

Conclusion

The experiments on Christmas Island established over the wet season during 2017/2018 revealed valuable information about agronomy, soil preparation, plant growth, and days to flowering between sites and soil treatments for the different hemp varieties. The preliminary results outlined above show the potential to grow Industrial hemp tropical varieties on Christmas Island; however, it will be essential to investigate nutrient deficiencies and the use of particular varieties to optimise growth before cultivation of hemp will be possible.

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Hemp production in Malawi with focus on harvesting date, retting process and fibre content

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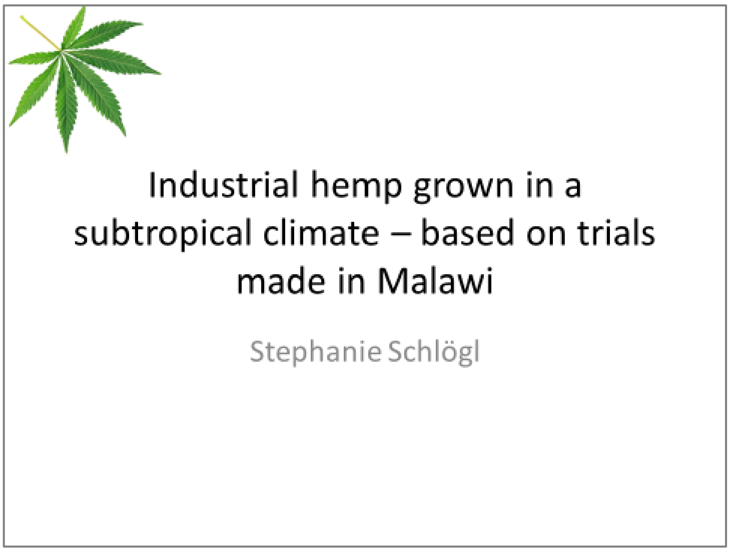

Materials & Methods

Figure 2 Measured and marked harvesting spot at cultivar Yuma trial plot, Malawi, 2017

Materials & Methods

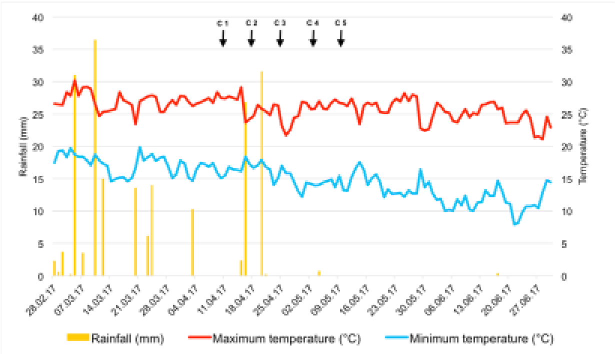

Figure 3 Temperature and rainfall during the whole vegetation period of the Yuma trial plot, Meteorology Centre of Chitedze Agricultural Research Station (CARS), Malawi, 2017

Results

Figure 4 Measurements of male plant height and stem diameter of one square meter cut harvested at cultivar Yuma trial plot, Malawi, 2017

Results

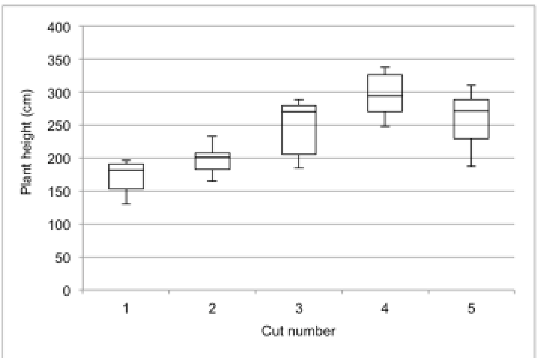

Figure 5 Male plant heights (cm) at the time of each cut, variety Yuma, Malawi, 2017

Results

Cut number	1	2	3	4	5
Harvesting date	11. Apr	18. Apr	26. Apr	03. Mai	10. Mai
11. Apr	1				
18. Apr	3	1			
26. Apr	4	3	1		
03. Mai	4	4	3	1	
10. Mai	5	4	3	3	1
17. Mai		5	4	3	2
24. Mai			4	4	3
31. Mai			5	4	3
07. Juni				5	4
14. Juni					4
21. Juni					5

1 - green hemp; 2 - beginning of retting, stem a little bit grey and fragile; 3 - first black fungus; 4 - 50% of the stem is black; 5 - retting completed

Table 1 Degree of retting for different harvesting dates, Malawi, 2017; visual observation

Results

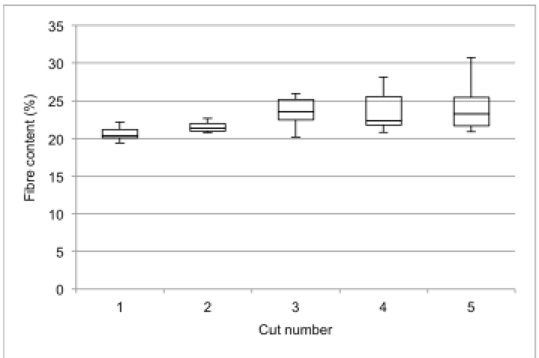

Figure 6 Total fibre contents (%) of both genders at the time of each cut, variety Yuma, Malawi, 2017

Local paper production

Figure 7 Artisan paper made in Dedza with fibre from cultivar Yuma trial plot, Malawi, 2017

Mechanical impact

Figure 8 Paper pulp production in Dedza, Malawi, 2017

Reason

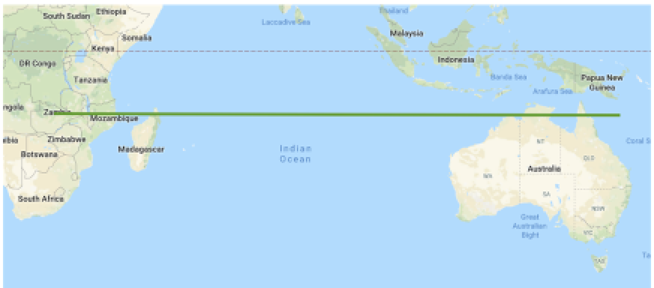

Figure 9 World map with the 14° latitude south marked

https://www.google.com.au/maps

Climate in Lilongwe

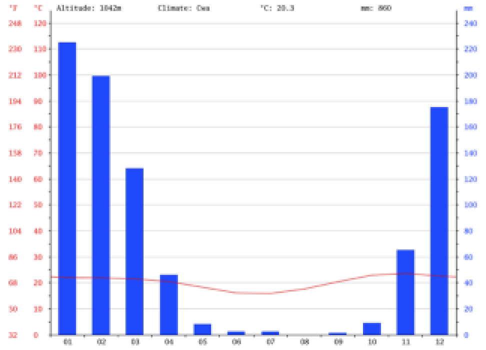

Figure 10 Temperature and interception in Lilongwe

https://en.climate-data.org

Climate in Mataranka

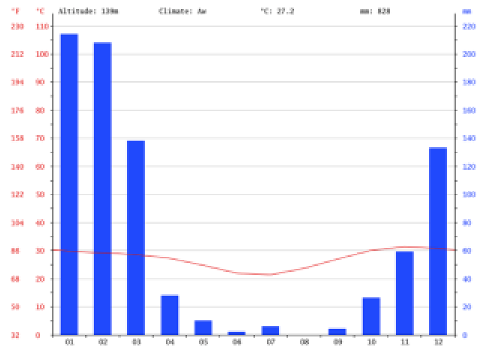

Figure 11 Temperature and interception in Mataranka

https://en.climate-data.org

Growth

Figure 12 Monitoring growth at four different dates from 31th March till 26th May 2017 at cultivar Yuma trial plot, Malawi, 2017

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invegrow hempower Malawi

ECOFIBRE Industries Operations

On-farm decortication

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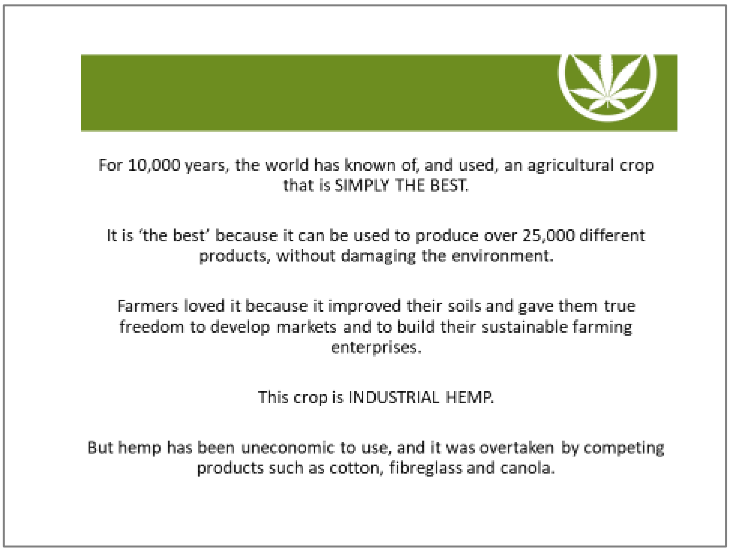

The most expensive step in using hemp was the process of separating the hemp stalk into its component parts of FIBRE and HURD; this process is known as 'DECORTICATION'.

Textile & Composite Industries Pty Ltd, driven by its philosophy of helping farmers to become more profitable, independent, environmentally green, and sustainable, has over the past 24 years developed a DECORTICATING MACHINE that eliminates these expensive processing costs.

THE OPPORTUNITIES IN THE HEMP INDUSTRY

There are excellent and highly-profitable opportunities for:

- Investors
- Farmers, (who can generate profits of up to $3000 per ha)
- Manufacturers
- Retailers, and
- Governments that seek to promote the creation of new jobs, new industries, and economic growth.

Contact TCI for further details of the opportunities and the financial aspects of those opportunities.

This Presentation is made in honour of Adrian Francis K. Clarke, the founder of TCI and the inventor of the world's best decorticator, a decorticator that does not need retting of hemp.

Adrian died on 15 October 2015. He dedicated the last part of his life to solving the major problem of the hemp industry: how to decorticate without retting.

Why did he do this?

This is the D8 Decorticator that overcomes the problem.

INVITATION: You are invited to come to Austeng, in Geelong, to see this decorticator in action, TOMORROW!

You can also see this D8 working in the videos shown on TCI's website at www.textilecomposite.industries

The D8 is so revolutionary in its effectiveness and design that some hemp 'experts' find it difficult to believe. And they wish to preserve the old style of decorticating WITH RETTING because that is what they know and what they have invested in.

These are ideal fibre hemp crops
These crops are 12 feet tall and were grown in 90-100 days.
They yield 3 tonnes of fibre, and 7 tonnes of Hurd, per hectare


Hemp fibre and hurd is now significantly more cost effective to produce WITHOUT RETTING by using TCI's D8 Decorticator. It now provides a very real substitute for existing products in the market.


After decortication in TCI's D8, this fibre can be used for composites in its raw state or degummed for textiles


The secondary product that is produced is the hurd.
Hurd can be used to make paper, cellulose plastics, cellulosic materials, fuel ethanol, building products and building walls.

A Hemp Hurd and binder wall.
This wall gives maximum insulation and yet it breathes.
It is also fire resistant.
Houses made from this are ideal for fire-prone areas.
Hemp houses are termite-proof and mould-free, in even the most humid areas.

Hemp composites are light and strong, the ideal natural replacement for fibreglass and some carbon fibre
Shipping pallets, caravans, trailers and car bodies can be made from TCI'S super-strong unretted hemp.

There are 9 Significant Advantages of Industrial Hemp:

1. Hemp is environmentally clean and causes virtually no damage
2. Hemp requires minimum fertilizers and no chemicals or pesticides
3. Hemp uses smaller amounts of water than comparable fibre crops
4. Hemp improves soil and can be regrown repeatedly in the same land
5. Hemp is easy to grow and can generate good profits for farmers if decortication without retting is available
6. Hemp is a natural anti-bacterial and anti-mould fibre
7. Hemp products of all descriptions each have competitive advantages
8. Value can be added to hemp raw materials in many different ways
9. Hemp products can be used locally and globally for different purposes and aimed for different markets.

Successful competition against all other products and successful global hemp industry growth requires 5 Strategic Initiatives.

1. Generate Market Demand for Hemp rather than Farmer Push.

Identify well-funded and successful businesses that have already publicly committed to reduce their negative environmental impact and EDUCATE THEM about the potential for unretted hemp to be the way that they can solve their environmental challenges

2. Embrace an abundance philosophy and not one of scarcity.

Hemp can radically improve the lives of 70% of the world's population who today cannot afford to buy a new cotton shirt. Future sustainable economic growth will come from this 70%, not the existing 30% of consumers.

3. Avoid commoditisation of hemp products.

Do not fall into this trap. Avoid the current fate of oil producers, iron ore producers, sugar cane producers: in their cases, it is the traders who make the largest profits, not the producers or growers.

Do not give away this magnificent raw material at a cheap price.

Remember this crucial fact: around the world, a pair of jeans can cost anything from US$20 through to US$900! And almost the same amount of cotton is used. Why do people pay $900 for a pair of jeans?

4. Harness the skills, experience and relationships in local communities to identify the hemp products that should be produced, and then supply the hungry markets that want these products both locally and globally

5. Educate your politicians in your country and enlist their support to succeed against the backlash of those established businesses who are opposed to hemp because of the potential impacts on their own businesses.

TCI considers that the best value-added hemp-based products to focus on in the next five years for both local and global markets are:

1. Fibre for clothing textiles
2. Fibre for biodegradable weed matting
3. Hurd for various building purposes
4. Hurd for horse bedding and poultry bedding
5. Seed for local planting or export for planting

6. Seed for cosmetics and food or export for cosmetics and food
7. Medical bandages
8. Fibre for composites particularly shipping pallets, building components, car parts, caravans and trailers
9. Fibre and hurd for edible food containers
10. Fibre and hurd to replace plastics generally
11. Hurd and fibre for paper
12. Ropes, baling twine, string: hemp baling twine can be safely eaten by farm animals, unlike polypropylene baling twine!

TCI's decortication technology enables Industrial Hemp to take its place in consumer markets

Hemp requires no toxic chemicals. It uses about the same water as a wheat crop, and uses less water than cotton.

It is ideal for organic and biodynamic production.

Hemp is naturally antibiotic and antimicrobial.

TCI technology slashes the cost of processing and starts its work on the farm so regional industries can flourish

The amazing strength and qualities of UNRETTED hemp fibre from TCI's D8 Decorticator have been verified by experts globally: samples are available for testing.

Industrial hemp, WITHOUT RETTING, can make an immediate, inspiring, nurturing, positive, sustaining and life-giving difference to the planet.

Take the next steps now, to more deeply understand the wonderful opportunities for governments, investors, farmers, manufacturers, and retailers.

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Worker health and wellbeing during cultivation and processing of hemp

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Abstract

The emergent Australian Hemp Industry is an important source of natural fibre and seed with a broad array uses including but not limited to; building materials, nutritional supplements, animal feed, therapeutic goods and as a source renewable biofuels. However, there are many occupational hazards that need to be managed to ensure safe and healthy working environments in this rapidly expanding sector. Health hazards of particular concern include inhalable dusts and biological aerosols, exposures to which have been associated with the occupational respiratory disease in the hemp textile industry for many years. Consideration for the potential for allergic responses from exposure to cannabis plants and their pollen, as well as exposure to infectious microorganisms is also required. This paper will provide an overview of biological hazards that may occur during the harvesting and processing of hemp for fibre and seed to provide guidance for producers on establishment of safe work places and practices at their workplace.

Introduction

Industrial hemp, formerly identified as *Cannabis sativa* L., is an ancient commodity that originated in central Asia around 8000BC, in the area that now covers Mongolia and southern Siberia [1]. Modern hemp applications are highly diverse including fibre, fuel, building, nutrition and medicine. Commensurate with the antiquity of the hemp trade, so too are occupational illnesses associated with the industry. In 1700, Bernardino Ramazzini wrote that employees working in the manufacture of hemp and flax textiles encountered grave hardships including the “offensive and highly injurious odours” associated with the retting (maceration) process to separate fibres, as well as the “foul and poisonous dust” that was emitted during the carding/combing of hemp that caused incessant coughing and asthma in workers [2]. More recently, medical practitioners in the 19th and 20th centuries referred to respiratory diseases such as “hemp fever” and Cannabosis, which in the present day is referred to as byssinosis, or commonly as Monday Morning fever [3]. As research and development into new applications for hemp based products gains momentum, so too does the potential for occupational illness during all phases from cultivation to usage of the end product. Biological, physical and chemical hazards may encountered starting from the cultivation of cannabis plants (heavy plant, agrichemicals, microorganisms), right through to the spinning and weaving of hemp based textiles (noise, dyes and organic dust). This article will focus on the biological hazards that are associated with the hemp plant and processes for the manufacture of textiles, which are associated with niche occupational illnesses within the textile industry. Control strategies to reduce worker exposure to organic dusts are also discussed.

The characterisation of respiratory hazards, particularly biological agents, is critical in the early diagnosis of occupational disease, but more importantly, in the design of safe work premises and practices that promote worker health and wellbeing. Table 1 describes the biological hazards that may be encountered from paddock to mill in the production of hemp fibre and textiles.

Table 1. Exposure to Biological Respiratory Hazards and their Associated Health Impact in hemp cultivation and textile production.

Process	Activities	Biological Respiratory Hazards	Health Effects
Cultivation and Harvest	Planting, thinning, maintenance of crops. Harvest is undertaken after flowering but before the seeds set	Seed dust	Anaphylaxis, bronchial asthma[4-6]
		Microorganisms and their constituents (bacteria, fungi, mould spores, endotoxin, glucans, mycotoxins etc.)	Airway irritation, hypersensitivity pneumonitis (extrinsic allergic alveolitis, farmer's lung), Organic dust toxic syndrome, chronic bronchitis, respiratory allergies, asthma, and asthma-like syndrome[7-9].
		Insects, snakes, spiders	Bites, stings, poisoning and transmission of infectious diseases i.e. tick-borne fever.
		Cannabis pollen and plant particles	Allergy, IgE-Mediated (type 1) Hypersensitivity[10], allergic rhinitis, allergic conjunctivitis[11], asthma[12], eczema and contact urticaria[13-15]
		Organic dust (bioaerosols) complex mixtures of animal, plant, histamine, insect and microbial materials including dander, faecal matter, plant particles, bacteria, fungi, toxins and pollens, ammonia adsorbed to particles etc.	bronchitis (acute and chronic), chronic obstructive pulmonary disease (COPD), mucous membrane irritation, byssinosis (Monday morning disease), non-allergic asthma-like condition, allergic asthma (atopic individuals), ODTS, hypersensitivity pneumonitis (farmer's lung)[16]
Retting	Field/Dew Retting	Microorganisms.	Infectious diseases/zoonoses
	Water Submersion in water	Mosquitoes	arthropod borne infectious diseases
	Enzymatic	Pectinases, hemicellulases and cellulases	Occupational asthma, allergenic sensitisation[17-19].
Baling and Storage	Inadequate ventilation, water ingress	Decomposition gases, oxides of nitrogen (silo gas).	Airways irrigation, asphyxiation, explosive atmospheres, silo fillers disease[20].

	open bales of spoiled product	Periodic acute massive and mouldy (PAMM) organic dust exposures.	Hypersensitivity pneumonitis, ODTS, occupational asthma, mucous membrane irritation, non-allergic and allergic asthma[16].
Product Refinement	. Breaking . Scrutching . Hackling . Roving	Inhalable organic dusts containing hemp particles	Byssinosis, bronchitis, OTDS, non-allergic asthma, mucous membrane irritation, hypersensitivy pneumonitis[21].
		Pollen	Allergic rhinitis, allergic conjunctivitis, asthma, eczema, atopic dermatitis[22].
		Microbial constituents, endotoxin, beta-glucan, mycotoxins	Byssinosis, bronchitis, OTDS, non-allergic asthma, mucous membrane irritation, hypersensitivy pneumonitis[23].
Spinning & Weaving	Wet Spun/Dry Spun	Inhalable organic dusts containing hemp particles	Byssinosis, bronchitis, OTDS, non-allergic asthma, mucous membrane irritation, hypersensitivy pneumonitis[20, 23].

Organic dusts, sometimes referred to as biological aerosols or bioaerosols, are potentially hazardous agents that workers may be exposed to at all stages of production from cultivation through to manufacture. The complex dusts encountered in agricultural environments are biologically active combinations of mostly particulates or organic compounds. Their constituents include, but are not limited to, plant fragments, pollens, insect parts/dander, faecal matter, microbial organisms and their constituents, crystalline soil particles, diesel particulate and agrichemicals. Their impact on respiratory health is dependent on the concentration, exposure time, composition, particle size, as well as intrinsic (genetics) and extrinsic (smoking, recreational activities, home environment) factors relating to the individual. Dust exposure can lead to irritant, or inflammatory or allergenic responses [16].

From harvest to final product, the hemp particulates produced during the separation and refinement of process can measure between 10 to 200 µm in length, with a smaller number in the range of 3-5 µm [20 & 24]. These particles, although larger in comparison to the fibres from cotton, flax and jute production [24] are also capable of eliciting the same symptoms of irritation and inflammation, as well as occupational respiratory diseases. In addition to the plant fibres, cannabis pollen is an aeroallergen that can cause allergic rhinitis conjunctivitis, and asthma [5, 11, 25 and 26]. Contact with and handling plant material may result in skin rashes (contact urticaria) [5]. During production employees may also be exposed microorganisms that may proliferate on plants during cultivation, during the retting process, or during baling and storage. Microbial contamination of hemp is not just a risk for infectious diseases, but also hazardous due to the presence of microbial constituents such as fungal glucans and mycotoxins, as well as bacterial endotoxins [16].

Occupational Diseases of Hemp Workers

Respiratory Disease

Byssinosis is one the classical respiratory diseases associated with the hemp industry, but although intensely studied in relation to textile and fibre production [21, 23, 27-32]. Research into prevalence and incidence of the disease in other sectors is non-existent. As early as the 1940's, byssinotic symptoms in hemp workers were being observed and recorded by occupational physicians [33-35]. Byssinosis is an asthma-like syndrome relating dust exposure during the processing of flax, hemp, and other natural vegetable fibres [24]. The common name, Monday morning fever, is given to byssinosis because workers experience symptoms of fever, dyspnoea and fatigue which ease over the course of the week, only to return the following Monday after a break in exposure over the weekend. Early researchers speculated that microbial contamination of crops (cotton, jute and hemp with endotoxin) were the cause of byssinosis [3]. The respiratory condition has been attributed to the presence of water soluble aminoglycosides on cotton, flax and hemp fibres, not the actual fibres [20]. Although the specific aetiology of the disease is still not well understood. There is no treatment for byssinosis except the removal of the patient from the dusty atmosphere.

In addition to byssinosis, Valic *et al.* observed chronic bronchitis and decreased pulmonary function in workers exposed to soft hemp dust [21]. Chronic bronchitis is one of the most common dust related respiratory diseases in the agricultural industries, and can lead to the development of chronic obstructive pulmonary disease in a worker with, or at increased risk of , developing emphysema [16]. Exposure to dust particles can irritate the mucous membranes of the nose, sinuses, eyes and throat causing rhinitis, sinusitis, conjunctivitis and pharyngitis respectively. Membrane irritation, including allergic rhinitis and sinusitis has been observed for workers handling hemp and cannabis [12, 30 and 36]. Non-allergic asthma like condition, also referred to as occupational asthma, has been documented in hemp workers [37]. Occupational asthma is a non-specific inflammatory-mediated response that causes symptoms such as chest construction, coughing and wheezing that commences with organic dust work exposure, but declines several hours after exposure ceases. In contrast, allergic (atopic) asthma is attributed to a specific allergen such as pollen, dust or mould [16], which may be present in hemp cultivation and processing environments.

Organic Toxic Dust Syndrome (OTDS), also referred to as atypical farmers' lung, mycotoxicosis or silo fillers lung, is a delayed-onset, non-allergic influenza-like condition and has been associated with exposure mouldy materials. These materials include spoiled hay, decomposing plant material, and contaminated silage, grain and animal feed. Workers at greatest risk of ODTS would those involved with baling of retted hemp, as well as opening, scrutching and breaking of baled hemp where there is potential for periodic acute massive and mouldy (PAMM) exposures. Hypersensitivity pneumonitis in contrast is a group of allergic type IV hypersensitivy pneumonitis diseases when the airways come into contact with specific agents. Farmers' lung is associated with exposure to thermophilic bacteria in mouldy hay or silage, while malt workers lung is related to Aspergillus clavatus exposure [16]. Given the potential for spoilage of hemp crops during retting or storage, there is a risk of workers developing farmers' lung if specific microorganisms are allowed to proliferate in crops.

Allergy/sensitisation

A sensitising agent causes exposed workers to develop an allergic reaction after repeated exposure to the substance. Cases of cannabis sensitivity have been documented in Croatian hemp workers [22] and also forensic laboratory employees [10 and 14]. Health conditions experienced by workers exposed to cannabis materials include urticaria and contact dermatitis from handling plant material, as well as allergic rhinitis, conjunctivitis and asthma. Employee education on the sensitising properties and potential health impacts hemp plant exposure should be included in health and safety training programs so that workers are made aware of the importance of reducing exposures, as well as signs and symptoms that may be an indication that they are becoming sensitised and may need to seek medical guidance. The training programs should also include preventative measures to reduce their exposure, as well as the signs and symptoms allergic disease. Exposure to cannabis seed dust can also induce anaphylaxis and bronchitis [4] making this a potential health risk for agricultural workers involved in sewing hemp crops, as well as those harvesting in related operations where seed is cropped for oil production, animal feed and nutritional supplements.

Promoting Worker Health and Wellbeing

The hiatus in occupational hygiene and epidemiology research in the hemp industry during the majority of the 20th century created gaps in our knowledge on the identification and control of health hazards. The management of risk associated with hemp production will promote worker health, wellbeing and capacity to work, as well as foster innovation, quality and efficiency through continuous improvement. The also will help prevent and reduce the number and severity of occupational illnesses and their associated costs [38]. The established relationship between hemp dust, chronic respiratory disease and allergy indicates that dust exposures should be maintained as low as reasonably possible (ALARP). In addition, dust associated with products used to dye hemp can also be harmful to health [20 and 39]. Dust control is particularly important at both the cultivation/harvest and textile production stages where potential for dust generation are greatest, and where microbial contamination may have occurred. This includes harvesting, storage and opening of bales, as well as carding, combing, drying, spinning and weaving. Cleaning facilities can also generate high dust exposures where activities such as the use of compressed air to clean machinery, or sweeping of floors could significantly increase worker exposure to inhalable aerosols. Guidance on dust control measures and other related health hazards in textile production could be extrapolated from cotton and wool sectors including publications such as the Health and Safety Executive's guidance on textile dust/fibres [20], while guidance on identification and control of respiratory hazards in the agricultural sector can be sourced from Safe Work Australia [40, 41], U.S. Occupational Safety and Health Administration [42] and the U.K. Health and Safety Executive guidance for industry [39]. There are no Australian occupational exposure limits (OEL) for inhalable hemp dust. However, there is the Safe Work Australia raw cotton dust workplace exposure guideline of 0.2 mg/m^3 8 hour Time Weighted Average (8-hr TWA), 4.0 mg/m^3 8-hr TWA for grain dust, as well as the Australian Institute of Occupational Hygienists (AIOH) recommended trigger level of 5 mg/m^3 (8-hr TWA) for inhalable dusts not otherwise classified could be applied [43]. Table 2 details specific recommendations to reduce worker exposure to dust.

Table 2. Potential Controls that can be applied to Reduce Organic Dust Exposure.

Hierarchy of Control	Process
Elimination and Substitution	Purchasing only quality feedstock. Reject products with microbial contamination. Instigate dustiness limit for incoming products.
Engineering and Isolation	Provide LEV provided at the feed point of opening machines, and automate process where possible to minimise manual handling. Enclose and install local exhaust ventilation for dust generating machinery/processes such a scrutching, carding, drawing, combing and spinning equipment. Installation of under machine extraction units to eliminate build-up of settled dust. General ventilation to reduce accumulation of dust indoors.
Administration	Training and education of employees on the respiratory and biological hazards associated with organic dusts, including hemp. Health surveillance program for respiratory disease. Introduce cleaning schedule including maintenance schedule for air filtration equipment (filter changes, duct cleaning and servicing).

	Clean equipment and premises using a HEPA vacuum suitable for industrial use or to use a piped vacuum system. Exploration of wet cleaning process to reduce potential for dust aerosolization.
Personal Protective Equipment (PPE)	Respiratory protection equipment (RPE) could be explored where engineering controls are impracticable.

While personal protective equipment (PPE) is often one of the first considerations for protecting the health and wellbeing workers, this is the least effective means of exposure control because it is dependent on the individual following proper procedure. Where PPE is provided as part of a risk management plant, employers must develop a PPE management plan, and undertake fit testing and training with employees in accordance with AS/NZS1715:2009 selection, use and maintenance of respiratory protective equipment. Health and safety knowledge and experience from related industries such as cotton and flax production could be adapted to hemp textile production, as well as other sectors using hemp such as the fabrication and use of building (hemp based concrete/insulation) and food manufacture.

Conclusion and Recommendations

The Australian hemp industry continues to expand, so too does the potential for worker exposure to potentially hazardous biological agents. There is an immediate need for the development of guidance materials on potential OHS hazards and their control. At present, the majority of epidemiological/ OHS data is based on hemp textile industry, which although useful in establishing preliminary guidelines, may not be appropriate for all applications. Given the wide diversity of hemp products that are produced and used in Australia there is a need for the characterisation of biological hazards, including organic dust exposures in other hemp based industries. It is recommended that a model code of practice or industry guidance materials be developed in relationship with industry to raise awareness of occupational hazards and their control in the workplace to promote the health and wellbeing of workers.

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Thursday, 1 March 2018

SESSION 6
Looking after seed value

Chair: Ruth Trigg, Secretary, Industrial Hemp Association of South Australia

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Chemical diversity in a global industrial hemp genetic resource collection
Mat Welling, Southern Cross University, NSW

Dedicated international-quality Cannabis seed-bank facilities for ex situ genetic resource conservation at Southern Cross Plant Science (SCPS, Lismore)
Jos Mieog, Southern Cross University, NSW

Industrial Hemp: Innovation and Commercialisation in Australia
Sally Davis, Davies Collison Cave P/L, VIC

Analysis and spatial distribution of hemp seed constituents compared to other edible seeds
Rachel Burton, Adelaide University, SA

Advances in leaf oils: Game-changing technology for oil production in biomass crops'
Thomas Vanhercke, CSIRO Agriculture, ACT

Chemical Diversity in a Global Industrial Hemp Genetic Resource Collection

Matthew Welling[1, 2], Lei Liu[1], Tim Shapter[2], Carolyn Raymond[1] and Graham King[1, *]

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Abstract
Cannabis produces a diverse range of metabolites including the illicit psychotropic cannabinoid delta-9-tetrahydrocannabinol (THC). Accurately determining the chemical constituents of *Cannabis* is necessary for the development of industrial hemp cultivars which can satisfy end-use market requirements and maintain regulatory compliance for THC. Multiple analytical chemical and genetic assays have been developed to predict cannabinoid composition. However, these methodologies have only been examined within a subset of the *Cannabis* genepool. A representative survey was conducted on a broad range of diverse *Cannabis* groupings derived from the Ecofibre global genetic resource collection using liquid chromatography-mass spectrometry (LC-MS) profiling as well as two dominant and co-dominant DNA SCAR markers. Heterozygote individuals exhibited up to three times the level of cannabinoid variation than had previously been identified. Non-conformity of the DNA markers was also observed in a plant individual which exhibited a complex cannabinoid profile. We propose a strategy which combines the DNA SCAR markers as well as exhaustive chemical profiling for accurate characterisation of cannabinoid composition. Further, more detailed comparative genomic analysis on a selected set of materials from the Ecofibre gene bank is currently underway, which may improve the accuracy of scoring chemical diversity in *Cannabis*, and may expedite DNA marker-assisted-selection (MAS) for the development of chemically elite industrial hemp germplasm.

Keywords: *Cannabis sativa* L, phytocannabinoids, diverse germplasm, metabolic engineering

References
Welling MT, Liu L, Shapter T, Raymond CA, King GJ (2016) Characterisation of cannabinoid composition in a diverse *Cannabis sativa* L. germplasm collection. *Euphytica*, 208: 463-475.

Chemical Diversity in the Ecofibre Global Industrial Hemp Genetic Resource Collection

Matthew Welling
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BClinSc, BEnvSc (Hons)

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matt.welling@scu.edu.au
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Overview

1. **Background**
   - Chemical phenotypes (chemotypes)
   - Biosynthetic/genetic model
2. **Research gaps**
   - What we can/can't genotype
3. **Objectives/approaches**
   - XP-GWAS

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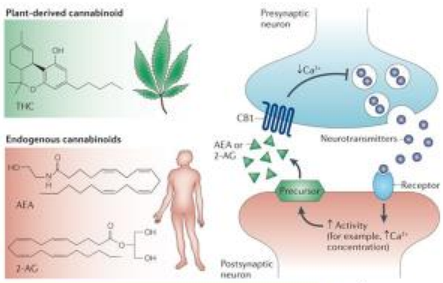
Cannabinoids

Secondary metabolites
- Female inflorescences
- Capitate stalked trichomes

Bioactive compounds
- Modulation human ECS
- Psychotropic effects (THC)

Chemotypes
- **Quantitative** (Content)
  - Conc. in plant tissue (**% w/w**)
- **Qualitative** (Composition)
  - Conc. in cannabinoid fraction (**% total**)



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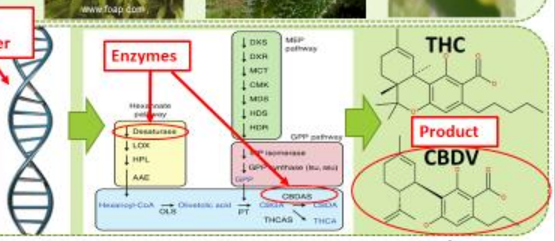
Chemotypes

Quantity (% w/w)
- Difficult to characterise
- Polygenic
- G X E interactions

Composition (% total)
- Easier to characterise
- Mono/oligogenic
- Strong genetic influence



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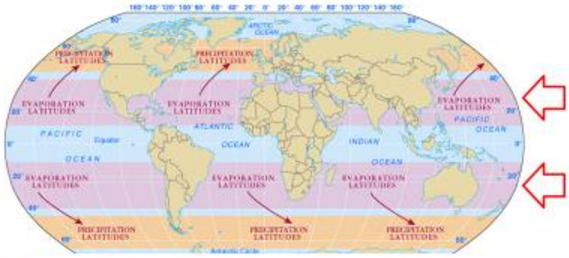
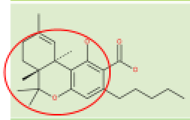
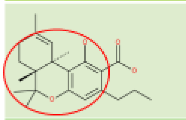
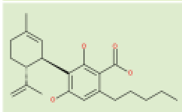
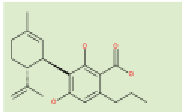


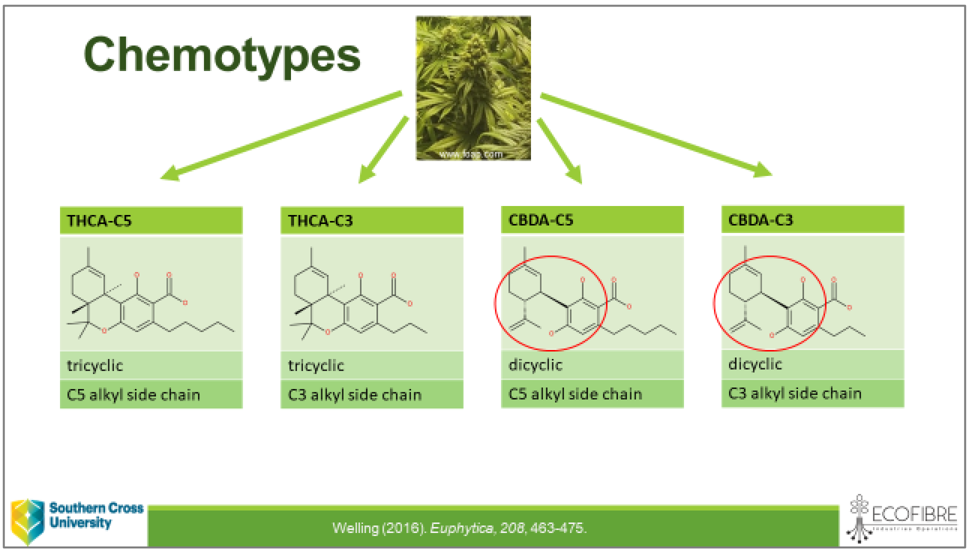
Germplasm	European	Asian
Australian latitudes	**Not matched**	**Matched**
Cannabinoid profiles	**Uniform** CBD	**Non-uniform** CBD, THC, CBDV…….
B_T alleles (THCAS genes)	**Low frequency**	**High frequency**

Southern Cross University — Hillig (2014). *J Forensic Sci, 59*, 919-926. Staginnus (2014). *J Forensic Sci, 59*, 919-926. Mandolino (2004). *Euphytica, 140*, 107-120. — ECOFIBRE

Chemotypes

THCA-C5	THCA-C3	CBDA-C5	CBDA-C3
			
tricyclic	tricyclic	dicyclic	dicyclic
C5 alkyl side chain	C3 alkyl side chain	C5 alkyl side chain	C3 alkyl side chain

Southern Cross University — Welling (2016). *Euphytica, 208*, 463-475. — ECOFIBRE


Chemotypes
THCA-C5
tricyclic
C5 alkyl side chain
THCA-C3
tricyclic
C3 alkyl side chain
CBDA-C5
dicyclic
C5 alkyl side chain
CBDA-C3
dicyclic
C3 alkyl side chain
Southern Cross University
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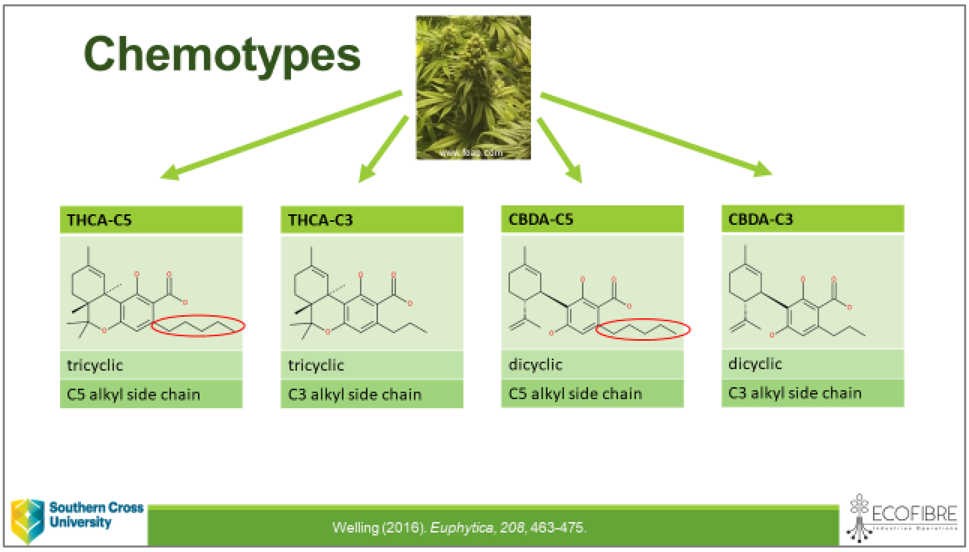
ECOFIBRE


Chemotypes
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tricyclic
C5 alkyl side chain
THCA-C3
tricyclic
C3 alkyl side chain
CBDA-C5
dicyclic
C5 alkyl side chain
CBDA-C3
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C3 alkyl side chain
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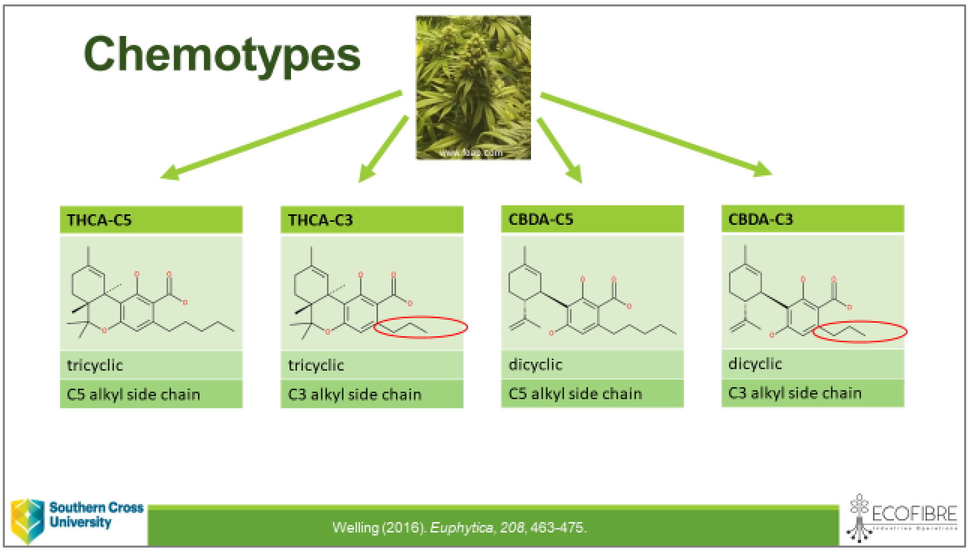
Chemotypes
THCA-C5
tricyclic
C5 alkyl side chain
THCA-C3
tricyclic
C3 alkyl side chain
CBDA-C5
dicyclic
C5 alkyl side chain
CBDA-C3
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C3 alkyl side chain
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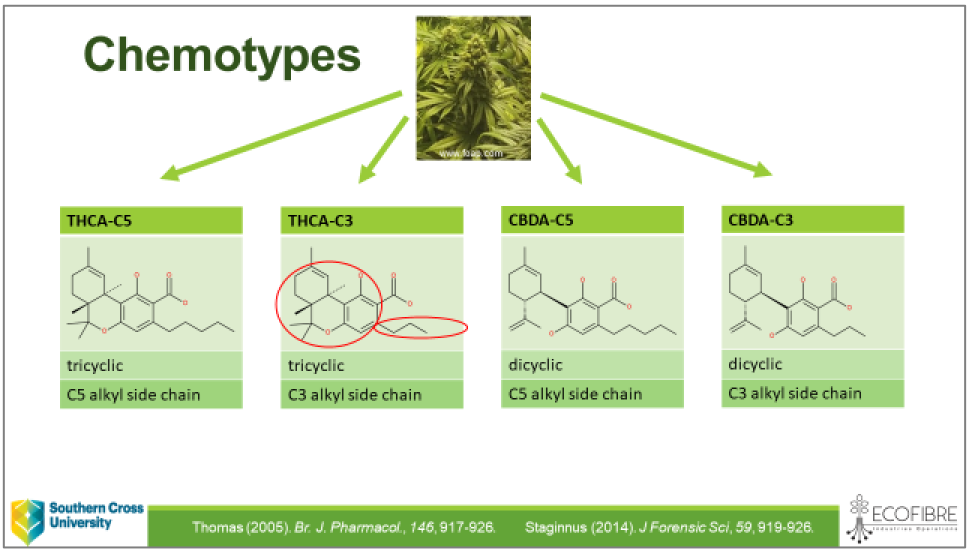
Chemotypes
www.fcaa.com
THCA-C5
tricyclic
C5 alkyl side chain
THCA-C3
tricyclic
C3 alkyl side chain
CBDA-C5
dicyclic
C5 alkyl side chain
CBDA-C3
dicyclic
C3 alkyl side chain
Southern Cross University
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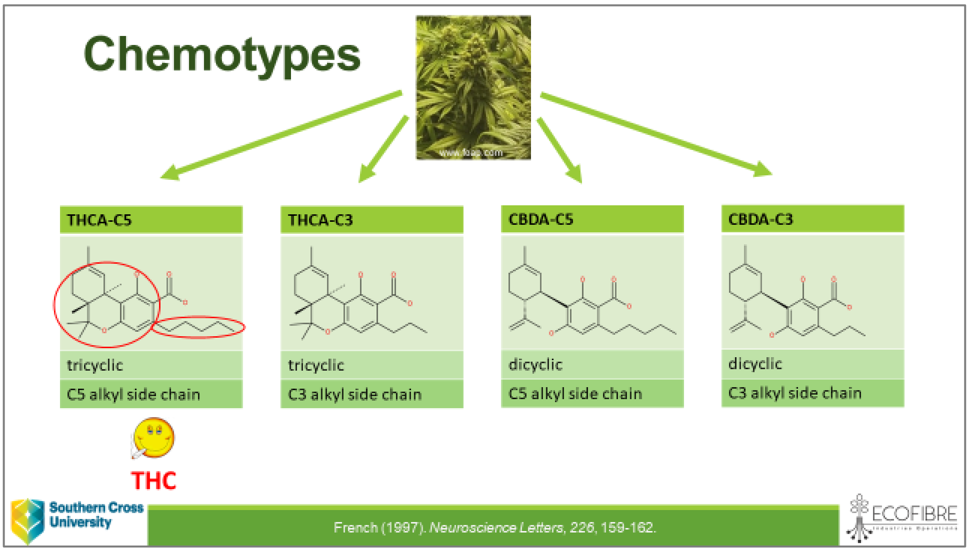
Chemotypes
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tricyclic
C5 alkyl side chain
THC
THCA-C3
tricyclic
C3 alkyl side chain
CBDA-C5
dicyclic
C5 alkyl side chain
CBDA-C3
dicyclic
C3 alkyl side chain
Southern Cross University
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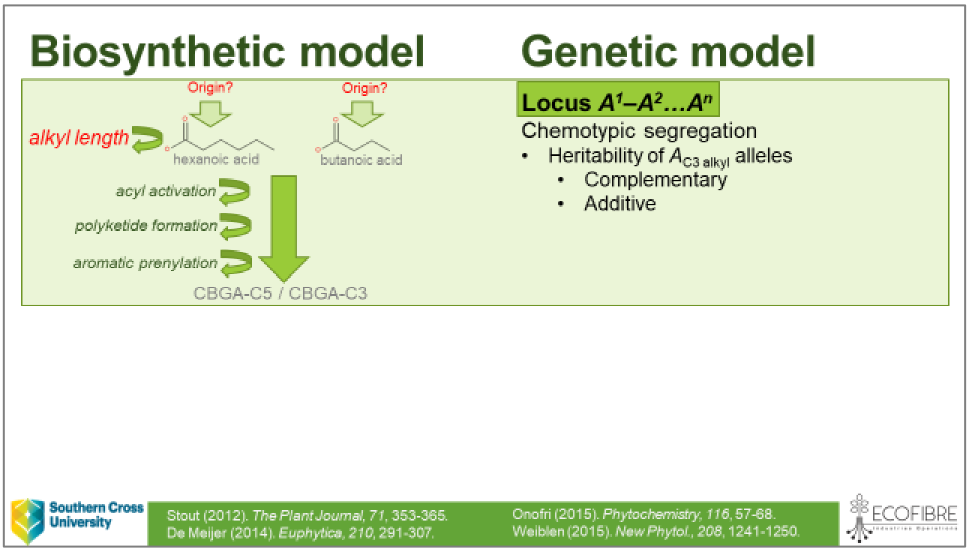
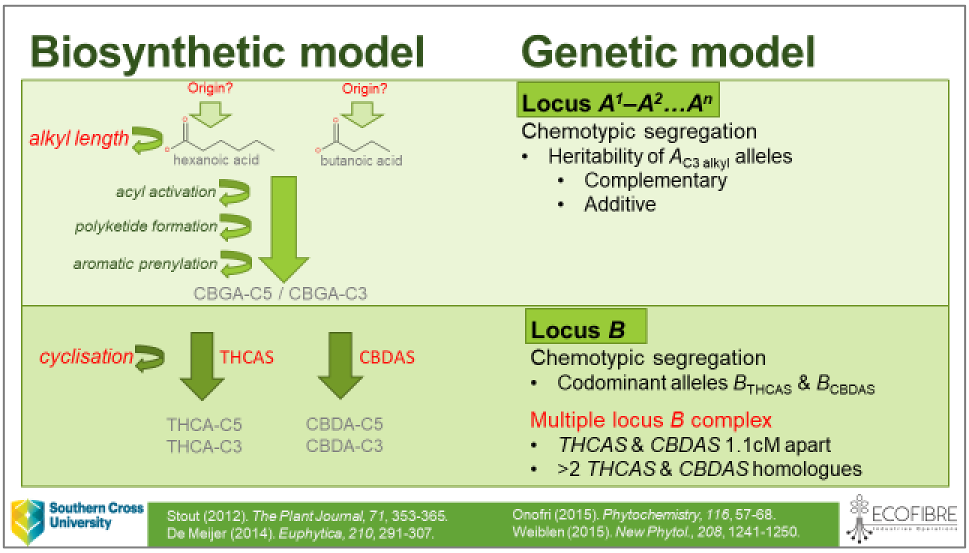
ECOFIBRE


Biosynthetic model
Origin?
Origin?
alkyl length
hexanoic acid
butanoic acid
acyl activation
polyketide formation
aromatic prenylation
CBGA-C5 / CBGA-C3
Genetic model
Locus A^1–A^2…A^n
Chemotypic segregation
• Heritability of $A_{C3\ alkyl}$ alleles
• Complementary
• Additive
Southern Cross University
Stout (2012). The Plant Journal, 71, 353-365.
De Meijer (2014). Euphytica, 210, 291-307.
Onofri (2015). Phytochemistry, 116, 57-68.
Weiblen (2015). New Phytol., 208, 1241-1250.
ECOFIBRE


Biosynthetic model
Genetic model
Origin?
Origin?
alkyl length
hexanoic acid
butanoic acid
acyl activation
polyketide formation
aromatic prenylation
CBGA-C5 / CBGA-C3
cyclisation
THCAS
CBDAS
THCA-C5
THCA-C3
CBDA-C5
CBDA-C3
Locus A^1–A^2…A^n
Chemotypic segregation
• Heritability of $A_{C3\ alkyl}$ alleles
• Complementary
• Additive
Locus B
Chemotypic segregation
• Codominant alleles B_{THCAS} & B_{CBDAS}
Multiple locus B complex
• THCAS & CBDAS 1.1cM apart
• >2 THCAS & CBDAS homologues
Southern Cross University
Stout (2012). The Plant Journal, 71, 353-365.
De Meijer (2014). Euphytica, 210, 291-307.
Onofri (2015). Phytochemistry, 116, 57-68.
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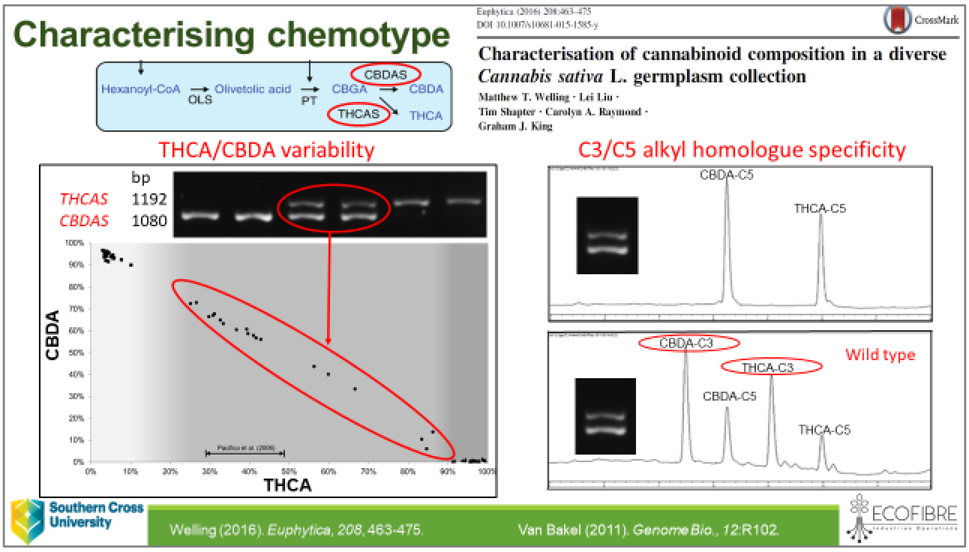
Characterising chemotype
Hexanoyl-CoA
Olivetolic acid
OLS
PT
CBGA
CBDAS
CBDA
THCAS
THCA
THCA/CBDA variability
bp
THCAS 1192
CBDAS 1080
CBDA
THCA
Euphytica (2016) 208:463–475
DOI 10.1007/s10681-015-1585-y
CrossMark
Characterisation of cannabinoid composition in a diverse Cannabis sativa L. germplasm collection
Matthew T. Welling · Lei Liu ·
Tim Shapter · Carolyn A. Raymond ·
Graham J. King
C3/C5 alkyl homologue specificity
CBDA-C5
THCA-C5
CBDA-C3
THCA-C3
Wild type
CBDA-C5
THCA-C5
Southern Cross University
Welling (2016). Euphytica, 208, 463-475.
Van Bakel (2011). Genome Bio., 12:R102.
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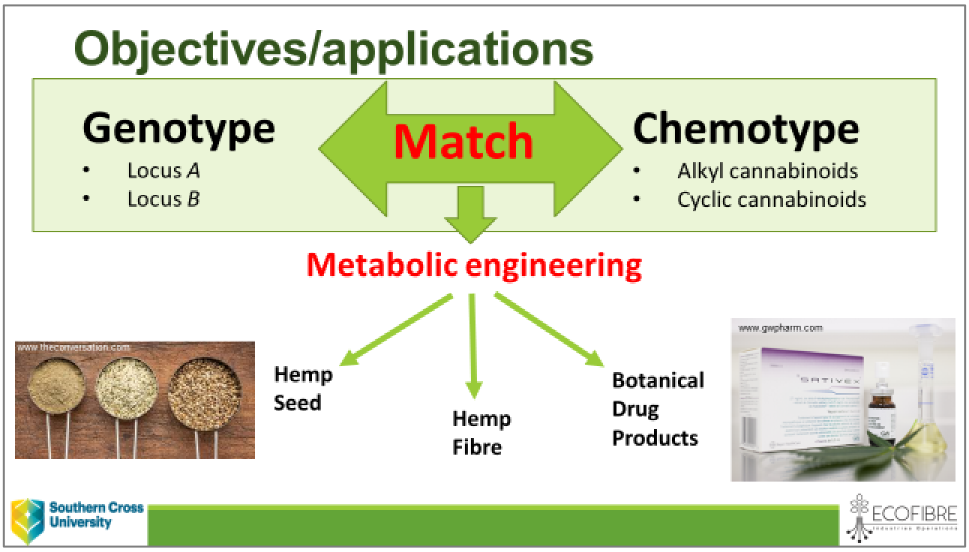
Objectives/applications
Genotype
• Locus A
• Locus B
Match
Chemotype
• Alkyl cannabinoids
• Cyclic cannabinoids
Metabolic engineering
www.theconversation.com
Hemp Seed
Hemp Fibre
Botanical Drug Products
www.gwpharm.com
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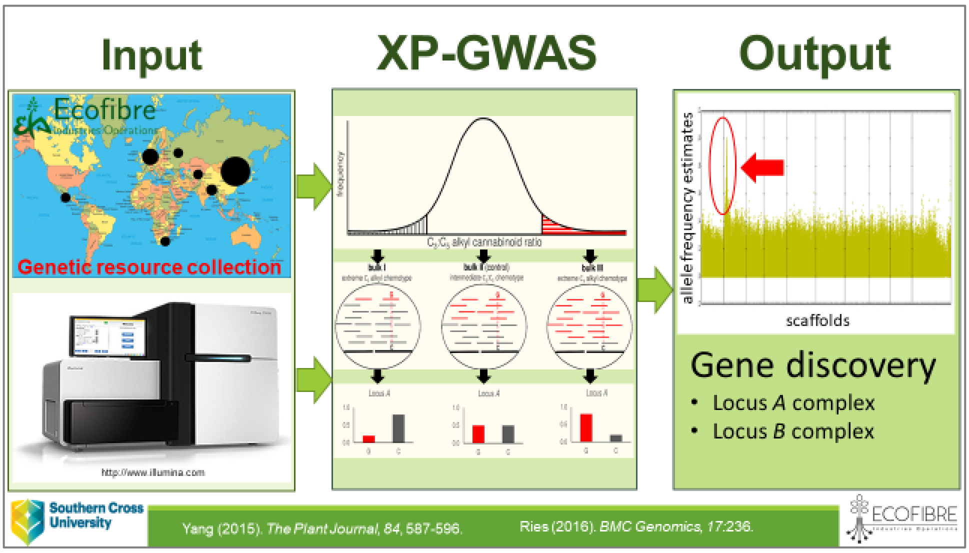

Conclusion

1. *Cannabis* contains **structurally diverse** & biologically active **cannabinoids**
2. Marker assisted selection could facilitate the metabolic engineering of *Cannabis* for specific end-use applications
3. The **genomic structure** governing alkyl and cyclic cannabinoid composition remains **under-characterised**
4. Comprehensive chemotyping of the genepool & **comparative genomic approaches** may improve the **accuracy** of scoring **chemotypic variation**

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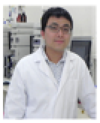
Acknowledgements

Prof. Graham King
Director of multidisciplinary research program.
Genetic analysis and data integration. Harnessing genetic and environmental variation.



Dr Ben Liu
Plant analytical chemist. Cannabinoid and terpene variation. Improving health aspects of seeds and functional foods.

Southern Cross Plant Science

Southern Cross University

Australian Government
Department of Education and Training

ECOFIBRE Industries Operations

Southern Cross University

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Dedicated international-quality *Cannabis* seed-bank facilities for *ex situ* genetic resource conservation at Southern Cross Plant Science (SCPS, Lismore)

Jos C. Mieog[1,*], Omid Ansari[2], Tim Shapter[2] and Graham J. King[1]
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[2]Ecofibre Industries Operations,
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Keywords: *Cannabis*, hemp, germplasm, SCPS, Ecofibre

Abstract

Plant genetic resource collections play a pivotal role in the efforts to improve the genetics of agricultural crops. Germplasm regeneration is a critical step in the successful maintenance of a genetic resource collection. The regeneration process aims to increase the quantity of seed stocks available for research use and to revitalise accessions that are exhibiting low viability. However, two main risk factors need to be carefully considered. Firstly, selection pressure could cause reduction of genetic diversity, and, secondly, outcrossing species may be contaminated with genetic material from outside the accession being regenerated (crosspollination). Addressing these concerns make establishment and maintenance of genetic resource collections costly.

Southern Cross Plant Science, in partnership with Ecofibre Industries Operations Pty Ltd, has established the facilities and tools required for a 'best-practices' *Cannabis* Genetic Resource Collection (seed-bank). These include; (a) a dedicated seed processing and storage room with controlled temperature and humidity to international *ex situ* conservation standards, (b) pollenproof growth chambers designed and owned by Ecofibre and (c) dedicated areas for the processing of harvested plants. All facilities have high-level security arrangements and have been set up to enable a high level of throughput.

Cannabis seeds are dried to equilibrium at 15°C and 15% relative humidity before being sealed in barcoded triple-layer foil packs for long-term storage at -20°C. Viability of accessions is determined via in-house germination tests according to the ISTA guidelines. Regeneration takes place in one of the 30 Ecofibre propriety pollen-proof growth chambers currently available, each of which can accommodate up to 20 plants at a time. These chambers provide a fully contained, temperature-controlled environment using an automatic watering system and meso-carbon filters for pollen filtration. To maximize the throughput, plants are grown under short-days flowering regimes, initially in a dedicated seedling growing station before being sealed into the growth chambers prior to flowering. Systematic phenotypic records, images and the sampling of tissues at different developmental stages provide added-value to the Ecofibre collection during this process. It is estimated that up to 160 accessions per year can be regenerated, with the facilities allowing for future expansion of the number of growth chambers.

Dedicated international-quality *Cannabis* germplasm facilities for *ex situ* genetic resource conservation at Southern Cross University

Jos C Mieog (MSc, PhD)

Southern Cross Plant Science, Southern Cross University

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Southern Cross University

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Germplasm collections

- Storage of living genetic resources such as seeds or tissues
- Long-term conservation of genetic variation
- Working material for breeders, researchers and other users
- Identification of 'core' collection
  - Represent genetic diversity of a larger collection
  - eg ~50 - 200 accessions
  - Reducing duplicate alleles between accessions
  - Does not replace main collection

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Establishing *Cannabis* seed-banks

- Extend lifetime of seed
- Aim for high viability at outset
- Insufficient data on long-term storage for hemp seed
  - need to monitor viability changes over time
- Periodic regeneration
  - Increase seed stocks
  - Revitalize accessions

15°C, 15%RH, Seed dried to 5% moisture content in 4 days

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Genetic Resource Databases

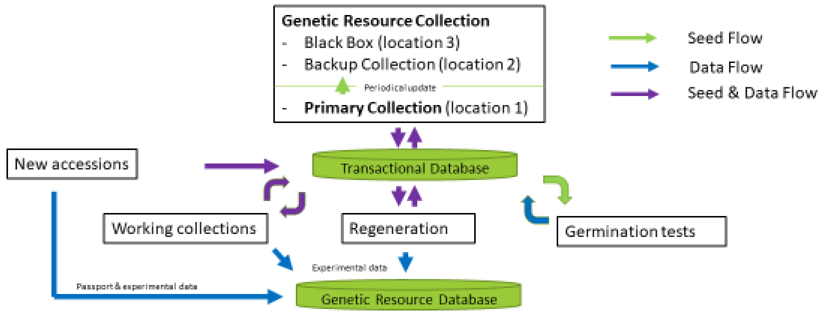
- Samples are added as **Accessions** (unique identifiers)
- Accessions are entered into two different types of databases

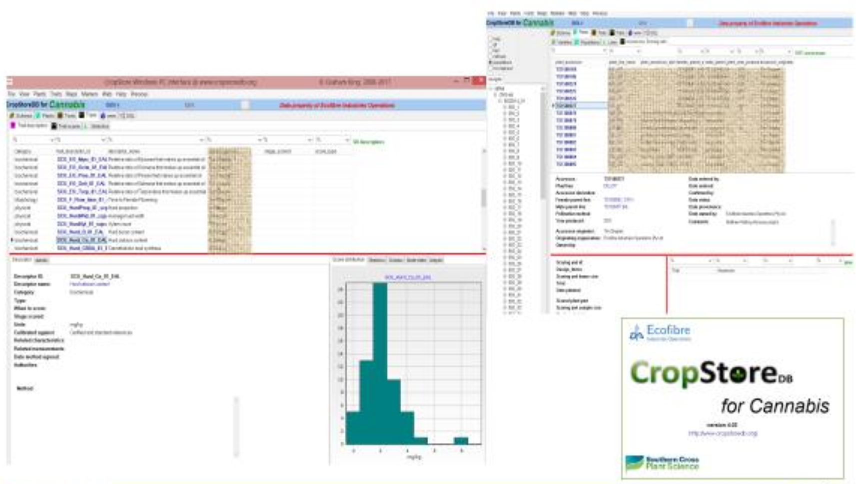
Genetic Resources Database (CropstoreDB)
- Provenance
- Lineage (lines, cultivars)
- Phenotypic data
  - Seed (size, color, weight, shape, NIR, FTIR)
  - Plant (images, sizes etc.)
  - Extracts (cannabinoids, essential oils)

→ compare accessions and correlate data

Transactional Databases
- Tracking seed packs (weights/number)
  - Primary collection
    - All accessions
    - Backups (spread risk)
    - Reference seed source (breeders/researchers)
  - Working collections
    - Subsets as required
    - Different locations
    - Research, pre-breeding, breeding

Databases and collections flow chart





Regeneration
Step 1: germination

- Dormancy
- Reviving old / sub-optimal seed
- Germination in controlled environment
  - on paper, water agar or soil
- Inadvertent selection?

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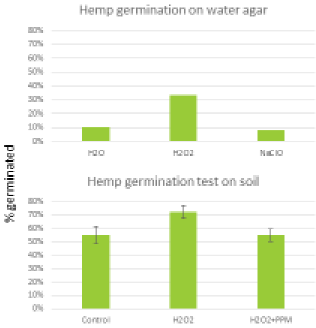
Germination tests

- H_2O_2 + bleach as anti-fungal treatment
  - Germination increased after H_2O_2 treatment
  - Bleach and fungicides had negative effect on germination
  - fungi/bacteria can persist
- Hypocotyl deformed on water agar
  - Can persist when transplanted

➡ Germinate in soil



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The role of H_2O_2 in germination

- Seed coat sterilisation with positive effect on germination rates
  - high concentration (1-30%), short duration
    - 3% for 10min for Zinnia
    - 3% for 4h or 30% for 50min for Douglas fir

➡ Higher germination rates attributed to reduction in fungus or increased permeability of seed coat?

- Seed **invigoration**
  - Low concentration (≤0.5%), longer duration (12-24h)
  - Induces ABA catabolism and GA synthesis
  - Shown positive effect in *Arabidopsis*, pea, coriander, carrot, almond and others

➡ Try H_2O_2 in combination with GA

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(Liu, Ye et al. 2010, Barba-Espin, Diaz-Vivancos et al. 2011, Imani, Rasouli et al. 2011, Szopińska 2014, Panngom, Chuesaard et al. 2018)

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Regeneration
Step 2: Grow out

- Ensuring genetic diversity is represented
- Logistical limitations – plant number per accession
- Minimising pollen-contamination
  - using Ecofibre pollen-secure chamber system
- Variation in seed set

➡ Maximise storage time before regeneration is needed!

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(Schoen & Brown 2001)

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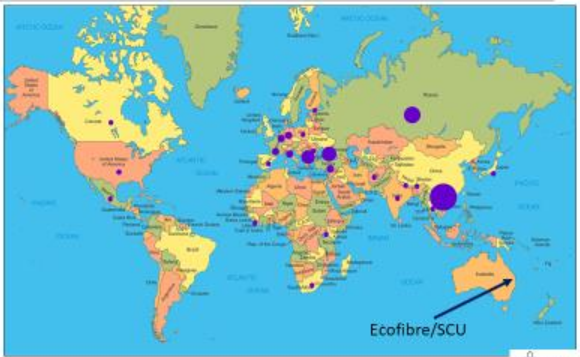
EcoFibre Hemp Germplasm Collection
curated by Southern Cross University

- Main collection = >1,400
- Core collection = ~320
- 270 landraces etc.



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Securing Ecofibre's germplasm

Existing stock → divide → dry → pack → secure

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Regeneration in pollen-secure chambers

Upgraded secure lab
+ chambers (30 total)
+ secure processing lab

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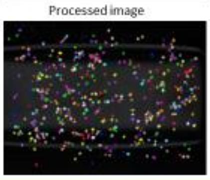
Adding value to the Collection

- ❑Seed weight
- ❑'Grainscan'
  - ❑size, shape and colour
  - ❑flatbed scanner
  - ❑filter out contamination
- ❑Images
  - ❑Standardized
  - ❑Before chamber phase
- ❑DNA samples
- ❑Measurements

Initial scan

Processed image



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(Whan, Smith et al. 2014)

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Australian National Cannabis Germplasm Resource

Conservation and systematic characterisation of genetic diversity

- **Seed bank**, with samples conserved to international standards
- **Herbarium** of voucher specimens
- **DNA bank** of extracted samples and sequence
- Extracted **cannabinoid bank** + **profiles**
- *Open-source* **database**

A Belated Green Revolution for *Cannabis*: Virtual Genetic Resources to Fast-Track Cultivar Development

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Capacity and Capability

Southern Cross Plant Science

Genetic Resources

- Glasshouse, Controlled environment, quarantine + q-labs
- Secure facility for ECOFIBRE pollen-proof chambers
- Secure low humidity seed bank facility
- Medicinal Plant Herbarium

Pre-breeding

- Genetic analysis
- Genomics, DNA assays, fingerprinting
- Bioinformatics
- Data integration

Chemistry

- Analytical Research Lab
- HPLC, GC, LC-MS
- TGA accredited
- Pilot scale extraction
- Environmental Analysis lab (*NATA acctd*):
  - heavy metals,
  - other contaminants

+ *Cannabis* Authorisation for R&D under NSW DMTA

Acknowledgements

Prof Graham J. King
Dr Kathryn Eales
Matt Welling (MSc)
Southern Cross Plant Science Centre, Southern Cross University

Dr Omid Ansari
Ecofibre Industries Operation

Thank you

Southern Cross University

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Industrial Hemp: Innovation and Commercialisation in Australia

Dr Sally J. Davis[1,*], Edith Hamilton[1] and Dr Alex Tzanidis[1]
[1]Davies Collison Cave Pty Ltd,
1 Nicholson Street,
Melbourne, VIC 3002

[*]sdavis@davies.com.au

Keywords: Industrial hemp; intellectual property; patents; plant breeders' rights; commercialisation

Abstract
It is estimated that industrial hemp is used in over 25,000 products across the agriculture, textiles, recycling, automotive, furniture, food and beverages, paper, construction and personal care sectors. Despite its broad applications, restricted cultivation and banning of human consumption in Australia has limited the ability of producers to capitalise on this versatile crop. Legalisation of cultivation and more recent changes in the food regulatory environment in Australia to allow for human consumption of hemp has expanded the scope for new products to enter the Australian market place.

In this economic growth area, it is important for researchers and entrepreneurs to recognise the benefits of securing appropriate intellectual property (IP) protection for new hemp innovations. Intellectual property rights that are particularly relevant to the hemp industry include patents, plant breeders' rights and trademarks. In this paper, the current Australian intellectual property rights that are available for hemp innovations will be outlined, with a specific focus on patents and plant breeder's rights. Thereafter, strategies for ensuring there is adequate and appropriate protection for hemp innovations in the current marketplace will be discussed, including freedom to operate considerations to ensure a clear path to market.

Introduction
Industrial hemp is a versatile and economical primary resource; however, restrictions on the cultivation of hemp and sale of hemp-derived products have limited the ability of Australian producers to capitalise on this versatile crop. The ability to cultivate and sell hemp-derived products is determined by state and territory legislation [1-8]. Currently, it is legal to cultivate hemp under licence in the majority of the states and territories, with the exception of the Northern Territory. The sale of hemp products is permitted in all of the states and territories.

It is recognised that there are a number of inconsistencies in the state and territory legislative framework (*i.e.*, acceptable levels of tetrahydrocannabiol (THC)), which makes it difficult to establish a robust domestic market for hemp production. Therefore, there has been a more recent push to harmonise the legislative framework for hemp production, as reflected by the recent changes to South Australian legislation to permit the commercial cultivation of hemp [9]. Furthermore, changes to federal food regulations to permit the sale of hemp-derived products for human consumption [10] have also indicated a shift towards a more liberal approach to the sale of hemp-derived products, which have been traditionally an export-only market for Australian producers.

As the legislative and regulatory frameworks in Australia become more permissive for both cultivation and sale of hemp-derived products, it is important that Australian producers secure appropriate intellectual property protection for their hemp innovations to ensure they are well placed to achieve their commercial objectives, whether that is commercialisation, licencing, developing research partnerships or sale to larger and/or international markets. Intellectual property rights that are particularly relevant to the hemp industry include patents, plant breeder's rights and trademarks.

In this paper, the current intellectual property rights that are available in Australia for hemp innovations will be outlined, with a specific focus on patents and plant breeder's rights (PBR). Thereafter, strategies for ensuring there is adequate and appropriate protection for hemp innovations in the current marketplace will be discussed, including freedom to operate considerations to ensure a clear path to market.

Intellectual Property Rights for Hemp Innovations

New hemp innovations are eligible for a range of intellectual property rights (IPR), including Plant Breeder's Rights, patents and designs, each of which offer differing scopes of protection. Furthermore, in some instances, the key differentiating factor between hemp products will be branding and market identity. These features may be protected with trademark registrations, which may cover multiple aspects of a brand and products thereof. In each instance, these intellectual property rights may exist concurrently to provide broad ranging protection in Australia. Although outside the scope of this article, it should also be recognised that corresponding rights may also be obtained in other jurisdictions, such as Europe and the United States, by filing applications for PBR, patents, and trademarks using national systems and well-established international intellectual property frameworks.

Plant Breeder's Rights

Plant Breeder's Rights (PBR) protection is available in Australia for new plant varieties that are created through traditional breeding programs and/or genetic engineering. To be eligible for PBR protection, a plant variety must be *new, distinct, uniform* and *stable* [11]. In order to be considered "new" a plant variety must not have been sold by, or with the consent of the breeder in Australia in the 12 months before the filing date of the PBR application, or outside Australia more than 4 years before the PBR application is filed (6 years for trees and vines) [12]. To be "distinct", a plant variety must have at least one key characteristic that distinguishes it from similar varieties known to exist at the time of filing the PBR application. A plant variety will be sufficiently "uniform" if any variations in key distinguishing characteristics are predicable. Finally, "stability" is satisfied where the key distinguishing characteristic(s) remain unchanged over successive generations.

Registered PBR offer a period of protection of up to 20 years for most plant species (25 years for grapevines and trees) [13]. The exclusive rights afforded by a registered PBR include the production or reproduction of propagating material; conditioning the propagating material (*i.e.*, cleaning, coating, sorting, packaging and grading); selling or offering the propagating material for sale; and importing or exporting the propagating material [14]. In limited circumstances, the exclusive rights afforded by registered PBR protection also extend to material harvested from the variety and "essentially derived varieties" (*i.e.*, varieties predominantly derived from the protected variety, retaining the essential features and not exhibiting any important features that differentiate it from the protected variety) [15].

Several varieties of industrial hemp (*Cannabis sativa L*) have been granted PBR protection in Australia. AgriFibre Industries Pty Ltd currently holds the largest number of PBRs for industrial hemp varieties in Australia. These industrial hemp varieties have been selectively bred for a number of specific applications, including next generation building materials, masonry, composite materials (*e.g.*, plastics reinforced with hemp fibres) and, more recently for human consumption.

Patents
In Australia, patent protection is also available for new plant varieties, as well as for plant parts (*e.g.*, seeds, whole cuttings, cells, cell lines and protoplasts), plant products (*e.g.*, fruit, flowers, oils, plant-derived compounds), bioprocessing (*e.g.*, methods of extracting plant-derived compounds) and methods of producing plant or plant varieties (*e.g.*, traditional breeding, genetic modification, marker assisted selection or embryo rescue). In the context of hemp, the subject-matter eligible for patent protection also includes the processes, equipment and systems for preparing hemp-derived materials and substances (*e.g.,* decorticating equipment). Patent protection can also be pursued for inventive downstream products using hemp-derived materials, as well as the processes, systems and equipment for making those products. The downstream products using hemp-derived materials can include fibre-based technology and high-performance materials, including composites.

To be eligible for patent protection, the invention must be at least novel and non-obvious [16]. Care must also be taken to ensure that the patent specification provides sufficient written description that would allow others to reproduce the invention [17]. For instance, a patent specification for a new plant variety should include a description of the parent strains, the method(s) by which the new plant variety was generated/selected and the phenotypic/genotypic characteristics of the new plant variety. In many cases, it can be very difficult to adequately describe in writing an invention that is, or relies upon the use of, newly identified biological material such as a plant or plant part. In those circumstances, the written description requirement can be satisfied by relying on a deposit of the plant material that has been at an international depository under the Budapest Treaty, bearing in mind that the deposit should be made before the initial patent application has been filed [18].

Other IPR
Other IPR that are relevant to the Australian industrial hemp industry include designs and trademarks. Design registration can be an important part of an IP strategy for protecting technical innovations as an alternative or addition to patent protections. Design registrations protect the appearance of a product, rather than how it works or how it is made [19]. A registered design can, therefore, provide significant protection in situations where patent protection is unavailable or not justified.

Trademark registration may be obtained for any “sign” (*i.e.,* names, words, logos, aspects of packaging, shapes, colours, scents, or combinations of these) that can be used to distinguish goods or services of one person from those of another [20]. Unlike business name registrations, registering a trademark provides its owner the exclusive right to use the mark in relation to the goods and services covered by the registration [21]. It also acts to prevent competitors from being able to register trademarks that might be considered too similar. In the context of hemp-related products, establishing strong brand and product identities is crucial to communicating the core value of the product and fostering customer loyalty. For example, hemp food products (*e.g.,* hemp oil, hemp protein, hemp seeds) are likely to be similar, if not identical to other products from other producers. Therefore, developing a strong brand identity is necessary to distinguish products and to make them more desirable to consumers, when compared to other similar products available.

The main requirement for registration is that the trademark should be capable of distinguishing goods or services. Marks which are simply descriptive of the goods and services or which consist of commonly used words such as “super” or commonly used logos such as plant leaves, may be difficult to register. Furthermore, with the recent legalisation of medicinal cannabis in Australia, there has been a corresponding increase in the registration of cannabis-related marks. This may impact upon the registration of marks for hemp products and services, particularly for marks that incorporate cannabis leaves, for example.

Strategy and Commercialisation

For IP rights to work effectively in a commercial context, it is important that an effective IP strategy is employed to ensure that there is adequate coverage for the commercial embodiment of your innovation, as well as market exclusivity. This typically begins by identifying the commercial embodiment of your innovation (*e.g.*, a product or process) and pursuing form(s) of IP (PBR, patents, trademarks) that will provide sufficient market exclusivity within budget.

Consideration must also be given to whether or not what third party rights already exists that may prevent you entering the market. To this end, conducting a thorough freedom to operate analysis prior to entering the market is a critical factor in any intellectual property strategy. Freedom to operate is determined by undertaking searching official IP databases, most of which are available online, to ascertain whether there are any third party rights, or potential rights, that may represent an obstacle to commercialisation and require prior authorisation from the IP rights holder (*e.g.*, a licence agreement).

Once the scope of the scope and type of IP protection has been identified, the enforceability of such rights will also need to be considered. For example, if patent protection is obtained for a method of manufacturing industrial hemp, consideration should be given to how easily an unauthorised use of the patented method could be identified from a competitor's product or entrance into the marketplace.

New product development and manufacturing infrastructure can also be expensive. The market exclusivity that is provided by registered IP rights can assist to attract investment and recoup R&D costs.

Consideration should also be given to *entitlement*, to ensure that clear title to the registered IP is established by appropriate contracts and agreements, in particular where the innovation has arisen from a collaboration between multiple groups.

Conclusion

Intellectual property is an important tool in the development and commercialisation of hemp-related innovation, particularly in view of the changing regulatory environment. Developing an appropriate strategy for pursuing intellectual property rights that are appropriate to the innovation is critical for securing market exclusivity and investment.

References

1. Hemp Fibre Industry Facilitation Act 2004 (ACT).
2. Hemp Industry Act 2008 (NSW).
3. Misuse of Drugs Act 2010 (NT).
4. Drugs Misuse Act 1986 (QLD), Part 5B and Drugs Misuse Regulation 1987 (QLD), Part 4.
5. Controlled Substances (General) Regulations 2000 (SA), Industrial Hemp Act 2017 (SA) and Industrial Hemp Regulations 2017 (SA).
6. Poisons Act 1971 (TAS) and Misuse of Drugs Act 2001 (TAS).
7. Drugs, Poisons and Controlled Substances Act 1981 (VIC) and Drugs, Poisons and Controlled Substances (Industrial Hemp) Regulations 2008 (VIC).
8. Industrial Hemp Act 2004 (WA)
9. The Industrial Hemp Act 2017 (SA) and Industrial Hemp Regulations 2017 (SA) came into effect on 12 November 2017.
10. Australia New Zealand Food Standards Code, under the Food Standards Australia New Zealand Act 1991 (Cth).
11. Plant Breeder's Rights Act 1994 (Cth), s 43(1).

12. Plant Breeder's Rights Act, s 43(5) and (6).
13. Plant Breeder's Rights Act, s 22.
14. Plant Breeder's Rights Act, s 11.
15. Plant Breeder's Rights Act, s 12.
16. Patents Act 1990 (Cth), s 7.
17. Patents Act 1990, s 40.
18. Patents Act 1990, s 6.
19. Designs Act 2003 (Cth), s 10.
20. Trade Marks Act 1995 (Cth), s 6.
21. Trade Marks Act, s 20.

Analysis and spatial distribution of hemp seed constituents compared to other edible seeds

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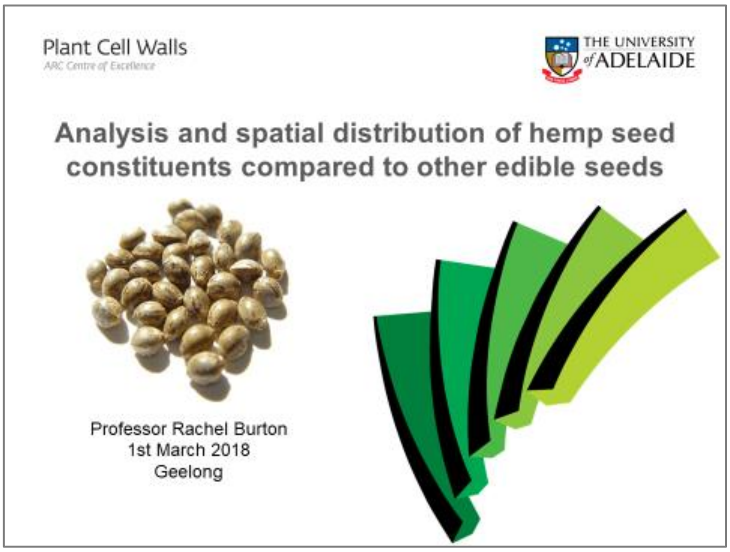
Abstract

Industrial hemp (*Cannabis sativa*) seeds are nutritionally rich in many compounds including oils, proteins and polysaccharides but some of these have not been profiled in depth. Hemp seeds are a nut with a hard carpel or exocarp called a hull, surrounding a soft inner heart. The hull is not as hard as for other nuts and so may be eaten, but very often it is removed to leave just the oil-rich hearts. The loss of the hull removes the majority of the seed mass that contains potentially valuable dietary components including fibre and antioxidants. Given the recent changes in legalisation allowing the consumption of hemp seed as food in Australia and New Zealand, definition of the nutritional profile of these seeds is of increased interest.

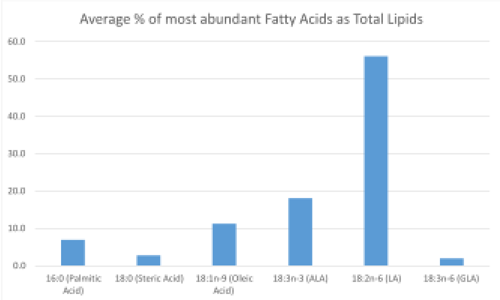
Detailed analyses of seeds from a range of hemp accessions provided indicative contents of oils, proteins and carbohydrates. From these experiments it is clear that hemp seeds possess a highly favourable omega 3:6 ratio compared to other plant sources whilst both quantitation of polysaccharides and the definition of their distribution in seed tissues using immuno-labelling with specific antibodies provides completely novel information about these components. Information about all these hemp seed constituents will be reported and discussed and used to compare against other important nuts and seeds used in human foods.



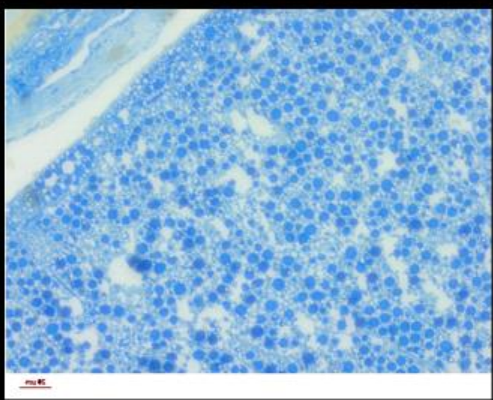
Screening for field testing

- Twenty lines acquired by Mark Skewes – not grown together
- Tested for the following;
  - Thousand grain weight; 11 to 46g – variable size
  - Heart to husk ratio; 1.1 up to 2
  - Lipid
  - Protein
  - Starch
  - Polysaccharides/sugars
- Microscopy to see what is where

Lipids

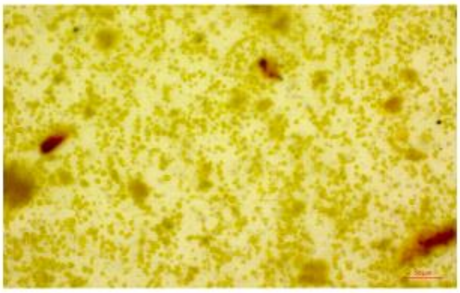


Range from 26.5 to 38% omega 3 14.1 to 25.7% 3:6 range 1:2.1 to 1:4.9



Protein bodies stained with Coomassie blue
Amounts from 19.5 to 26.9%

Spot the starch granules……



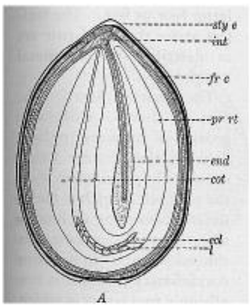
Polysaccharide summary

Component (% w/w)	Hull	Heart
Cellulose	22-37	0.00
Xylose	6-17	0.55
Galactose	0.55	0.00
Arabinose	0.65	0.65
Glucose	0.10	0.10
Sucrose	0.70	3.75
Fructose	0.10	0.08
Raffinose	0.00	0.45
Starch	0.00	Trace

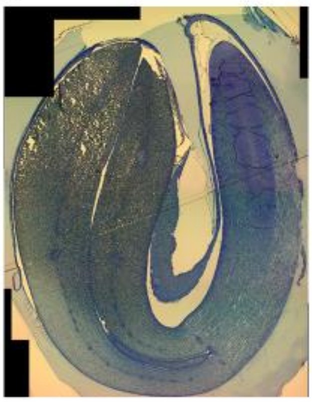
These analyses will be repeated on the 5 trial varieties grown in Loxton and Kybybolite

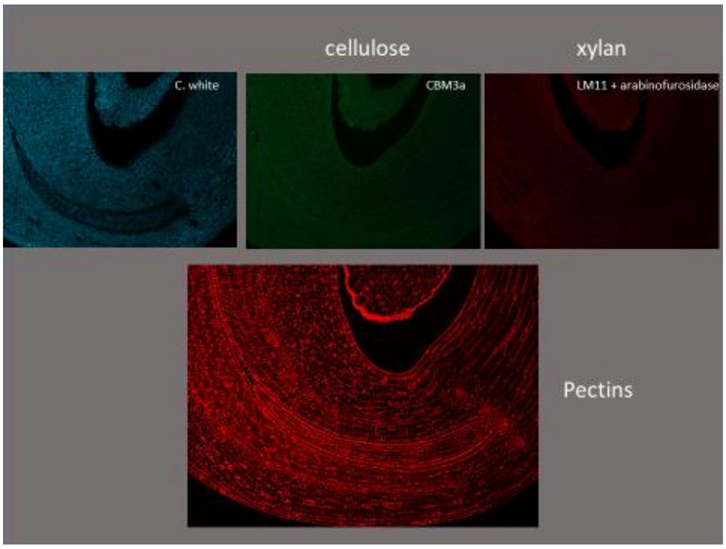
Seed cross-section

Herman E. Hayward, Professor of Botany at The University of Chicago, 1938

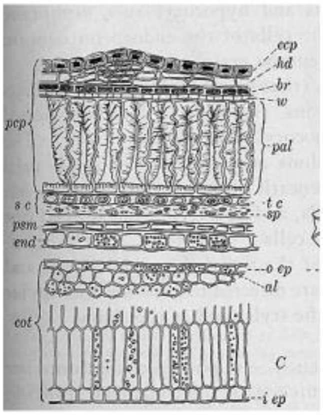


www.empology.org



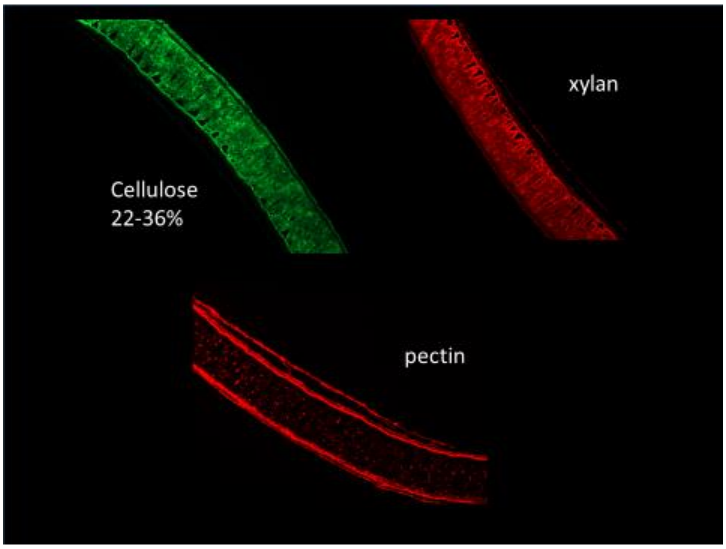


Structure of the hull

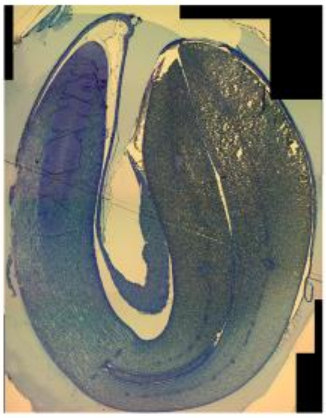


Herman E. Hayward

www.hempology.org



Cell wall summary



Cell walls in heart:

- ✓ Pectins (LM19, LM20, LM6, LM5)
- ✓ Xyloglucan (LM15)
- ✓ Callose
- ✓ AGP (JIM8, LM2)
- ✖ Mannan
- ✖ Crystalline cellulose (CBM3a)
- ✖ BG
- ✖ Xylans (LM10, LM11)

Cell walls in hull:

- ✓ Crystalline cellulose (CBM3a)
- ✓ Xylan (LM10, LM11)
- ✓ Pectin (LM19, LM20, LM5)
- ✓ AGP (LM2)
- ✖ Mannan
- ✖ Xyloglucan(LM15)
- ✖ Callose
- ✖ BG
- ✖ Pectin (LM6)
- ✖ AGP (JIM8)

Potential anti-nutritive components

- The seeds were not tested for phytates – these compounds can bind to other nutrients and hinder their bioavailability
- The hull stained strongly for lignin – this is not a surprise as there is likely to be secondary thickening in this tissue. Lignin adds to fibre and "chewiness" but too much may make seeds unpalatable
- Are the protein bodies homogeneous or do they have a more indigestible outer layer that interferes with breakdown and absorption? (known for sorghum)

Summary

- Consumption of the hearts will provide lipids with favourable omega 3 to omega 6 content, high protein but very little dietary fibre
- Consumption of wholeseeds will provide much more dietary fibre, although this may not be highly fermentable (cellulose and lignin)
- Current legislation may limit the consumption of wholeseeds but the best form would be ground
- Anti-nutritive components currently unclear
- Bioavailability currently unclear


Acknowledgements
Jakob Schultz
Kylie Neumann
Sandy Khor
Wai Li Lim
Mark Skewes and David Lewis
All the seed suppliers, including
ECOFIBRE

Advances in leaf oils: Game-changing technology for oil production in biomass crops

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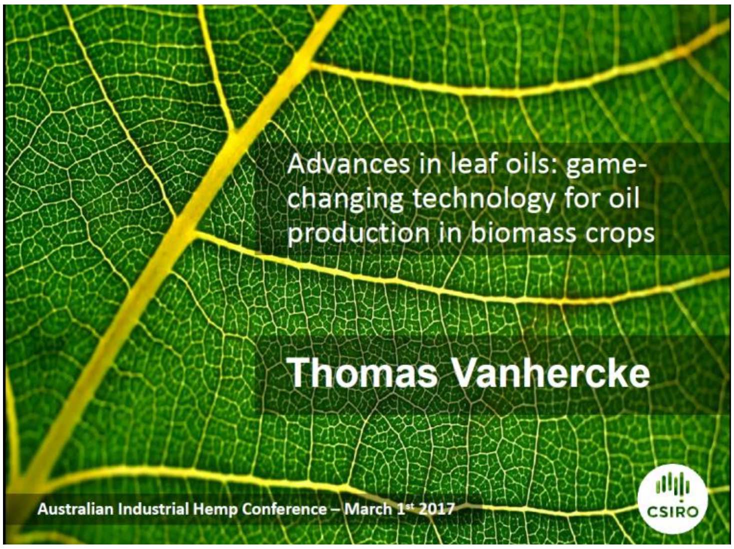
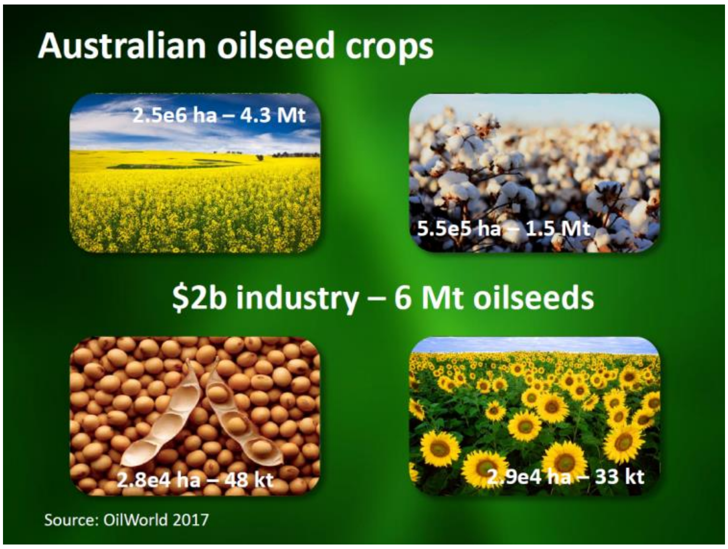
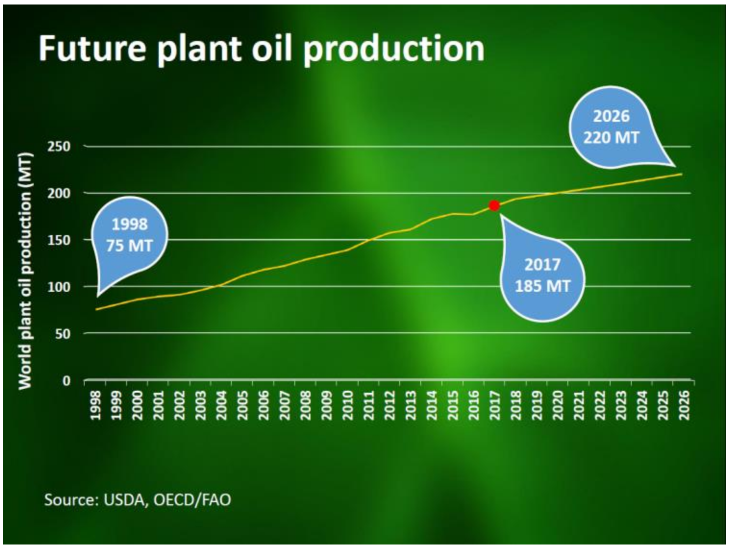
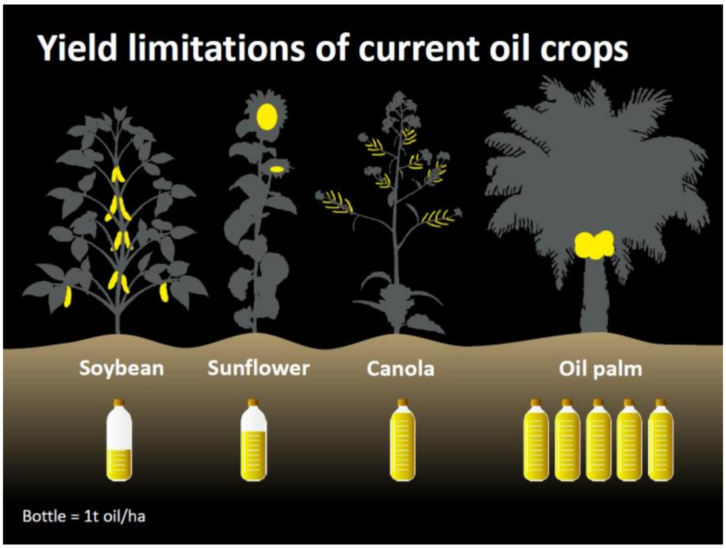
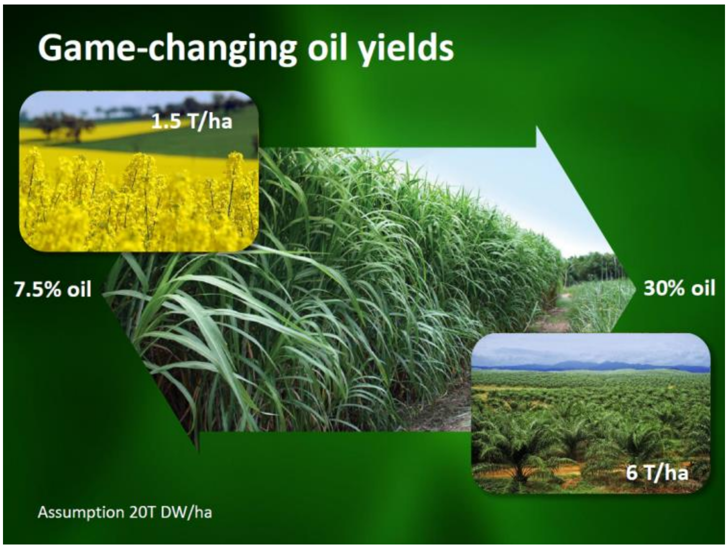
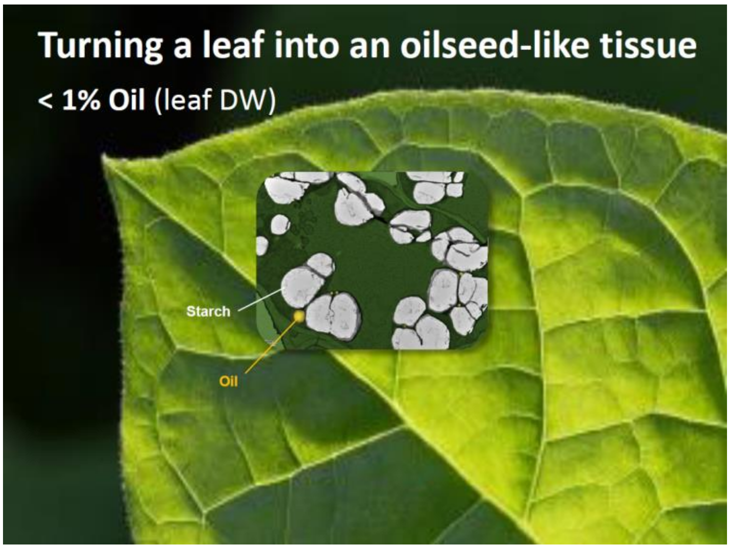



Australian oilseed crops
2.5e6 ha – 4.3 Mt
5.5e5 ha – 1.5 Mt
$2b industry – 6 Mt oilseeds
2.8e4 ha – 48 kt
2.9e4 ha – 33 kt
Source: OilWorld 2017

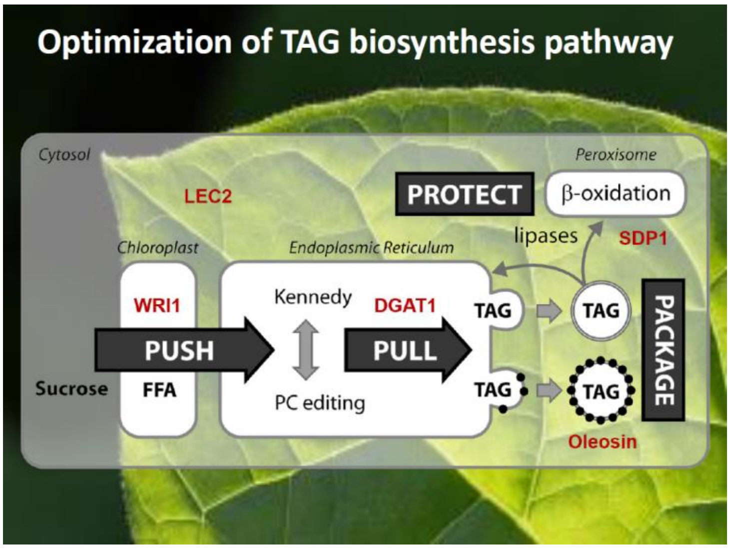

Future plant oil production
World plant oil production (MT)
250
200
150
100
50
0
1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026
1998
75 MT
2017
185 MT
2026
220 MT
Source: USDA, OECD/FAO

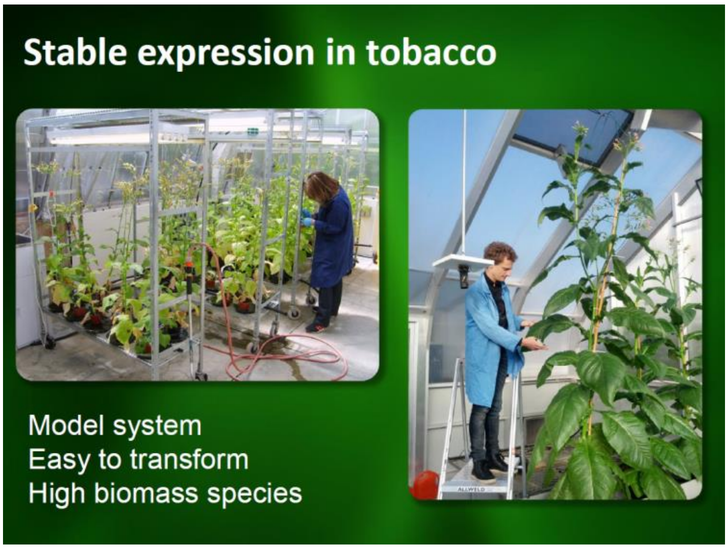

Yield limitations of current oil crops
Soybean
Sunflower
Canola
Oil palm
Bottle = 1t oil/ha

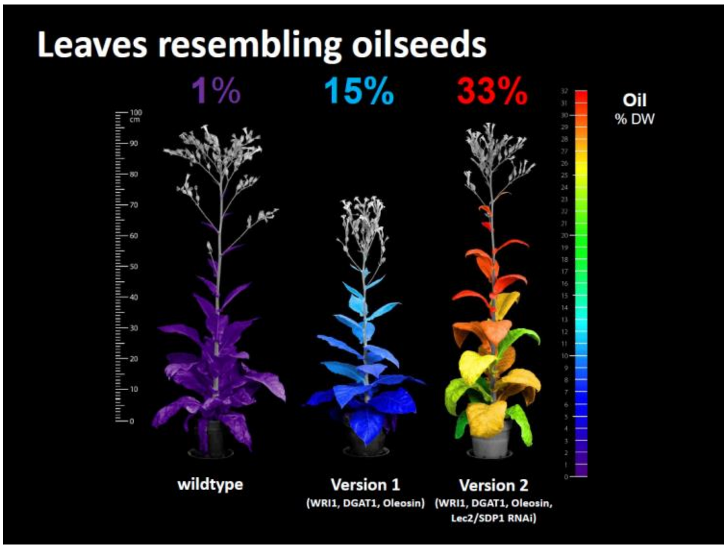

Game-changing oil yields
1.5 T/ha
7.5% oil
30% oil
6 T/ha
Assumption 20T DW/ha

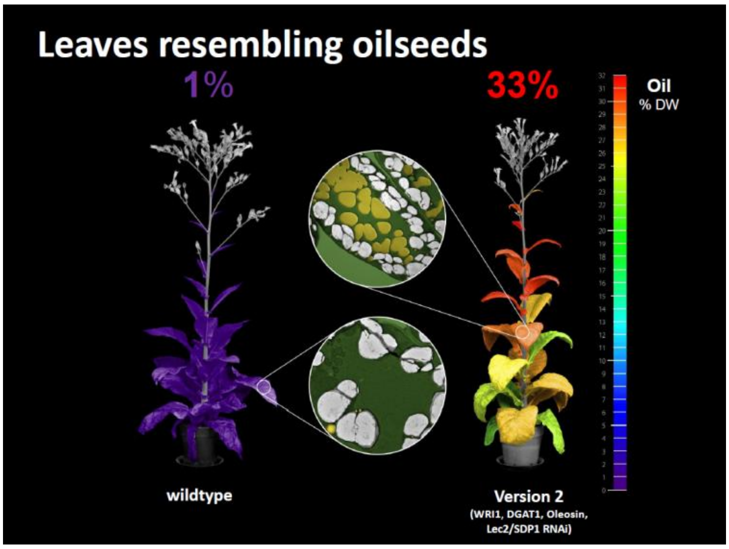

Turning a leaf into an oilseed-like tissue
< 1% Oil (leaf DW)
Starch
Oil


Turning a leaf into an oilseed-like tissue
> 30% Oil (leaf DW)


Optimization of TAG biosynthesis pathway
Cytosol
Peroxisome
LEC2
PROTECT
β-oxidation
lipases
SDP1
Chloroplast
Endoplasmic Reticulum
WRI1
Kennedy
DGAT1
TAG
TAG
PUSH
PULL
PACKAGE
Sucrose
FFA
PC editing
TAG
TAG
Oleosin


Stable expression in tobacco
Model system
Easy to transform
High biomass species


Leaves resembling oilseeds
1%
15%
33%
Oil
% DW
wildtype
Version 1
(WRI1, DGAT1, Oleosin)
Version 2
(WRI1, DGAT1, Oleosin, Lec2/SDP1 RNAi)



Leaves resembling oilseeds
1%
33%
Oil
% DW
wildtype
Version 2
(WRI1, DGAT1, Oleosin,
Lec2/SDP1 RNAi)

Profile shift towards lower desaturation
Wildtype
Transgenic
TAG composition (%)
0
10
20
30
40
50
60
70
C16:0
C18:0
C18:1
C18:2
C18:3n3
C20:0
other

Engineering energy dense fodder crops
CSIRO
AMFORA


Engineering extractable oil levels
CSIRO
NxtOil


Engineering extractable oil levels
CSIRO
NxtOil


CSIRO Leaf Oil team
Prof. Kent Chapman (UNT), Dr Phil Bates (USM), Drs Peter Eastmond & Fred Beaudoin (Rothamsted)
CSIRO

Thursday, 1 March 2018

SESSION 7
Fibre and hurd products

Chair: Charles Kovess, Managing Director TCI, VIC

The world fibre market
Stuart Gordon, CSIRO Manufacturing, VIC

Fibre products from industrial hemp
Menghe Miao, CSIRO Manufacturing, VIC

Investigation of wash behaviour of hemp-based denim substrate
Saniyat Islam, RMIT, VIC

Building an integrated energy storage from hemp plant materials
Carl Martel, Independent Scientist, Canada

Hemp building products
Glen Ossy-Orley (for Klara Marosszeky), Total Hemp Company, WA

The world fibre market

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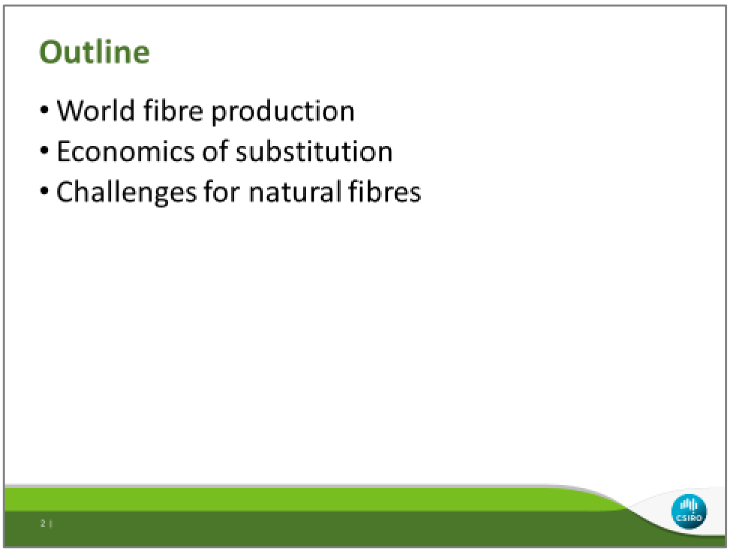
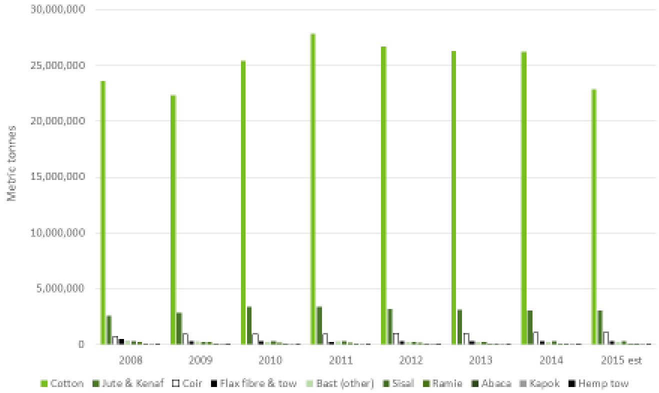


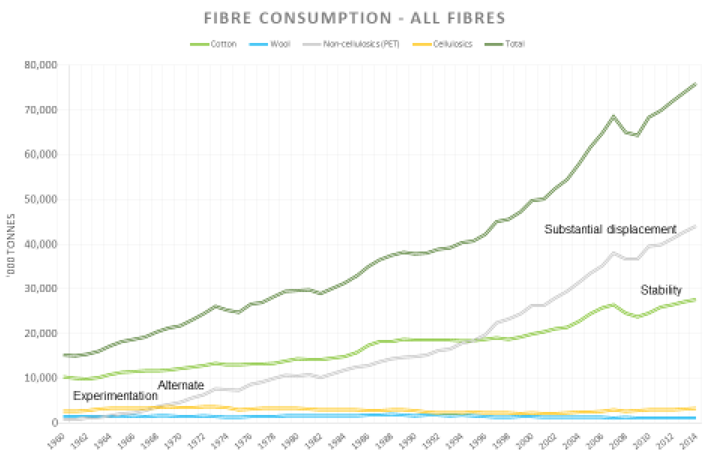
World natural fibre (vegetable) production



3 |

World fibre production

4 |



5 |

Substitution

The model describing substitution

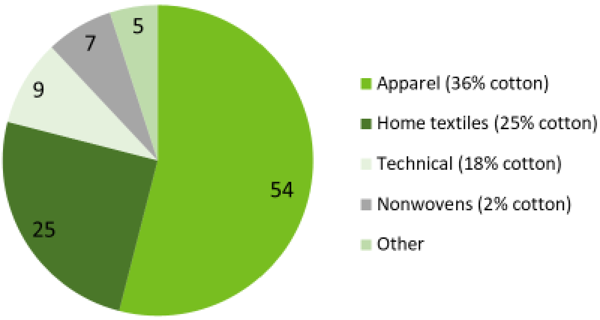
Substitutes are 'new'

Substitutes start high in price, limited in supply, not feasible for widespread use

Decay of 'old' fiber market share begins

Decay of 'old' fiber market share continues but flattens

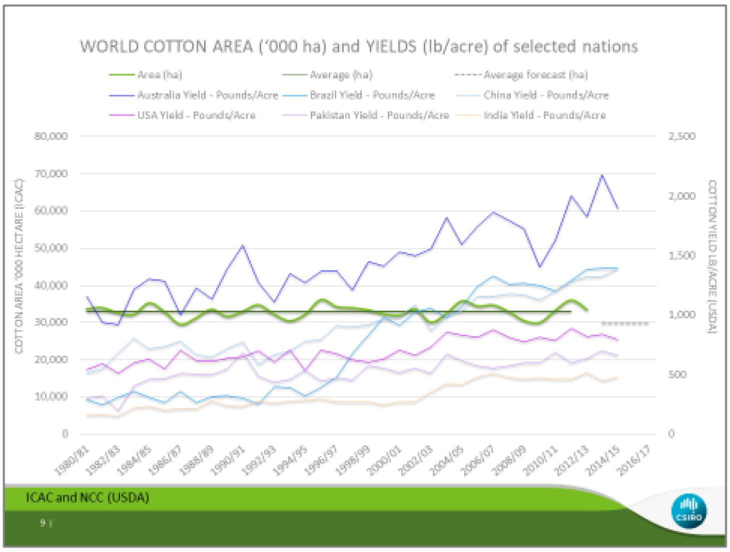
Substitution in textile market (>100 Mt in 2018)

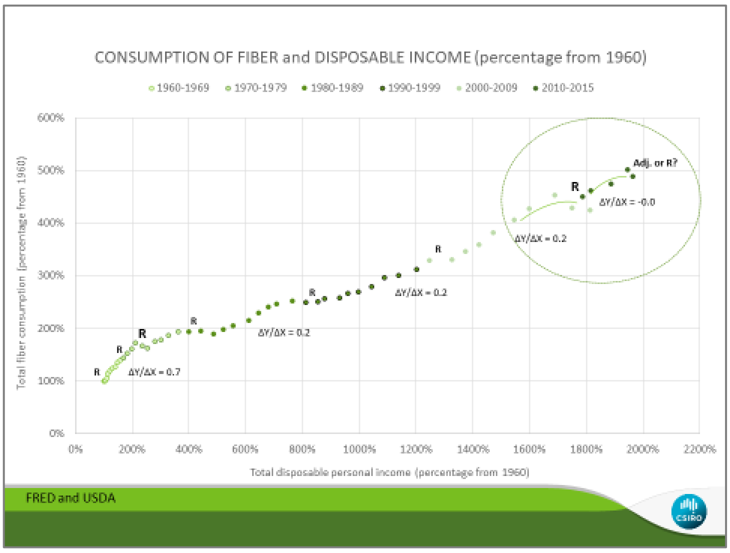


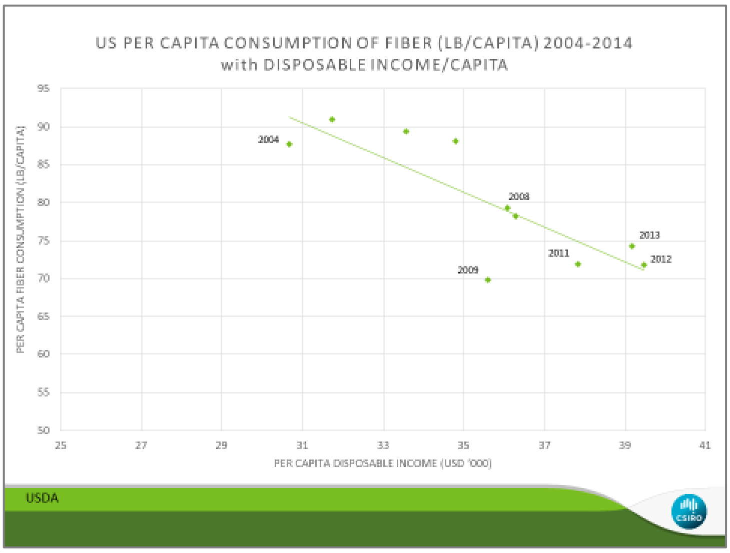
From FAO World Apparel Fibre Consumption (FAO-ICAC, 2013)

Economics of substitution

- Popultion, income and land
  - Important crops
  - Consumption increases with income
  - Finite land resources
- Price, supply, technology and 'story'
  - Demand and supply
  - Properties
  - Intangibles


WORLD COTTON AREA ('000 ha) and YIELDS (lb/acre) of selected nations
Area (ha)
Average (ha)
Average forecast (ha)
Australia Yield - Pounds/Acre
Brazil Yield - Pounds/Acre
China Yield - Pounds/Acre
USA Yield - Pounds/Acre
Pakistan Yield - Pounds/Acre
India Yield - Pounds/Acre
COTTON AREA '000 HECTARE (ICAC)
COTTON YIELD LB/ACRE (USDA)
ICAC and NCC (USDA)
9 |


CONSUMPTION OF FIBER and DISPOSABLE INCOME (percentage from 1960)
1960-1969
1970-1979
1980-1989
1990-1999
2000-2009
2010-2015
Total fiber consumption (percentage from 1960)
Total disposable personal income (percentage from 1960)
ΔY/ΔX = 0.7
ΔY/ΔX = 0.2
ΔY/ΔX = 0.2
ΔY/ΔX = 0.2
ΔY/ΔX = -0.0
Adj. or R?
FRED and USDA


US PER CAPITA CONSUMPTION OF FIBER (LB/CAPITA) 2004-2014
with DISPOSABLE INCOME/CAPITA
PER CAPITA FIBER CONSUMPTION (LB/CAPITA)
PER CAPITA DISPOSABLE INCOME (USD '000)
2004
2008
2009
2011
2012
2013
USDA

Demand elasticity for Australian cotton

Average and distribution statistics on cotton prices between 2006 and 2014 for five competing growths; means tested using Tukey's post-hoc analysis

Variable	N	Mean	SE Mean	St Dev	MIN	MAX
AUE	1263	105.02 A	1.07	37.89	58.75	248.25
UZE	1251	102.87 A B	1.21	42.67	54.75	256.50
T1E	1235	99.28 B C	1.11	39.14	50.00	238.50
A index	1230	97.36 C	1.12	39.13	53.05	243.65
AZE	1145	96.77 C	0.90	30.52	56.75	235.00
S7E	996	88.82 D	0.74	23.22	55.00	178.00

12

Demand elasticity for Australian cotton

Price elasticities of demand for Australian and competing export growths

Variable	Elasticity (2006-2014)
AUE	-0.1221538*** (-3.07)
AZE	-0.5099434*** (-16.58)
S7E	-0.2561016*** (-12.94)
T1E	-0.1310576*** (-4.45)
UZE	-0.5019768*** (-27.09)
Observations (for each growth)	1810**

*Note: Figures in parentheses are t-statistics; ***statistically significant at the 1% level; **includes use of predicted values in lieu of missing values for 2006-2014*

13

Challenges

- Fibre quality
- Post-harvest processing efficiency and quality
- Information supply to the supply chain
- Substitution of natural fibres on price (and quality)
  - New MMF with 'new' properties and function
  - MMF marketing (pricing) and support
- Loss of market share
- Acreage/environmental/identity concerns

14 |

Opportunities

- Improved fibre quality and information – lessons from MMF
- Improved 'traditional' products (become niche)
- New markets for natural fibre and natural fibre crop by-products
  - Chemical industries
  - Composites
  - Other products
- Marketing

15 |

Thank you

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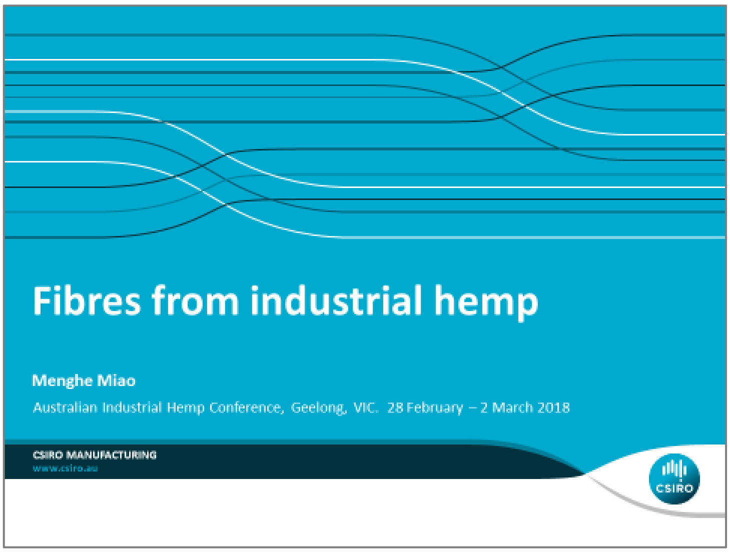
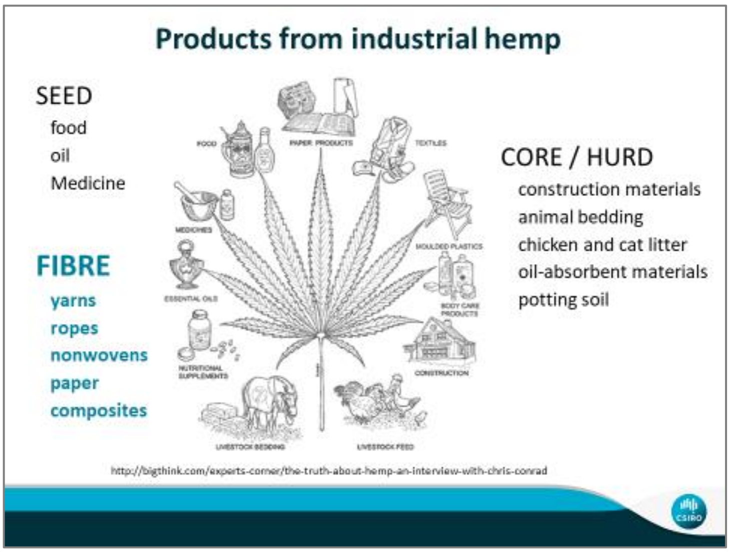
Fibre products from industrial hemp

Menghe Miao,
CSIRO Manufacturing,
Waurn Ponds, VIC 3216

menghe.miao@csiro.au



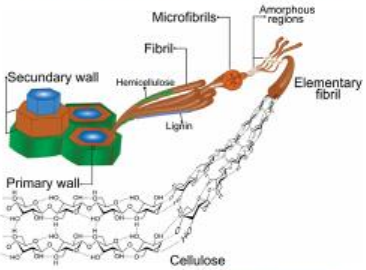


Fibre from the hemp stem

https://commons.wikimedia.org/w/index.php?curid=7902103

https://commons.wikimedia.org/w/index.php?curid=2304060

Structure of cellulose fibre



J rojas, M Bedoya and Y Ciro, Chapter 8 in "Cellulose - Fundamental Aspects and Current Trends", DOI: 10.5772/61334.

Fibre properties

Fibre	Density	Elongation	Strength		Modulus	
	g/cm³	%	MPa*	cN/tex#	GPa*	cN/tex#
Flax	1.5	2.7 – 3.2	500 – 1500	54	27.6	1800
Hemp	1.47	2 - 4	690	47	70	2170
Jute	1.3	1.5 – 1.8	393 - 773	31	26.5	1720
Cotton	1.5	7		32		500
Polyester	1.4	15		50		1100
E-glass	2.5	0.5	2000 - 3500	75	70	2940
Carbon	1.8	1.4 – 1.8	4000	-	230-240	-

* J Holbery and D Houston, JOM, 2006(Nov). 80-86.
\# Morton and Hearle, Physical Properties of Textile Fibres

Traditional hemp harvesting, retting and scutching

https://commons.wikimedia.org/w/index.php?curid=4473335

http://healthiscurrency.blogspot.com.au/2014/06/the-hemp-decorticator.html

Traditional uses - spinning

http://www.hemptraders.com/

World production of hemp fibres since 1960

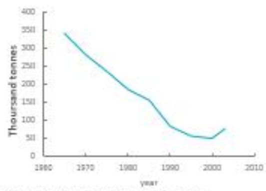
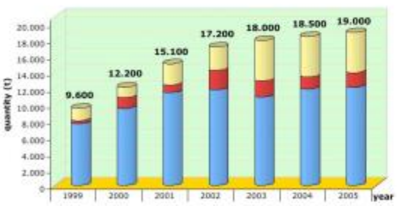


Table 4.10 World production of hemp fibre (tonnes) 1961–2003

Year	Tonnes	Year	Tonnes	Year	Tonnes	Year	Tonnes
1961	299,923	1972	271,467	1983	154,636	1994	51,909
1962	304,549	1973	266,777	1984	152,906	1995	56,636
1963	310,775	1974	260,460	1985	157,157	1996	65,837
1964	339,596	1975	236,234	1986	c 163,000	1997	63,506
1965	340,821	1976	238,046	1987	167,516	1998	73,629
1966	368,373	1977	233,658	1988	152,049	1999	61,140
1967	348,338	1978	215,318	1989	107,814	2000	50,618
1968	300,486	1979	207,200	1990	83,997	2001	60,917
1969	297,691	1980	186,443	1991	66,442	2002	67,950
1970	280,278	1981	149,097	1992	76,331	2003	77,450
1971	282,269	1982	133,792	1993	63,568		

Source: FAOstat.



Natural fibre use in German automotive industry

M Karus, et al. Nova-Institute. December 2006.

Mass production of short fibres

Chopping and decorticating

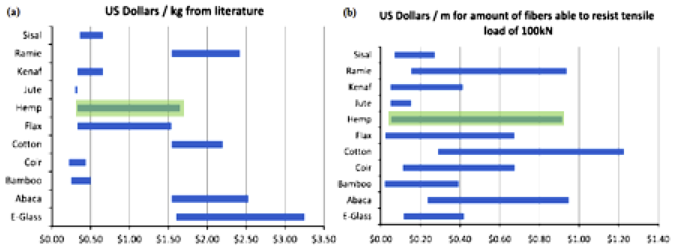
https://commons.wikimedia.org/w/index.php?curid=14636012

Decorticated/Hammer-milled Hemp Fibres
– different grades of fibres

- Longer fibres: 50 - 120 mm
- Can be used in nonwoven for a wide range of applications

- Short fibres: 2 - 10 mm
- Can be milled for injection moulding

Fibre price



Yan, L., Chouw, N. and Jayaraman, K., 2014. Flax fibre and its composites–a review. *Composites Part B: Engineering*, 56, pp.296-317.

10 | Presentation title | Presenter name

Why natural fibres?

- **Environmental benefits at disposal (replacing plastics)**
- Sustainable supply
- Agriculture opportunities – dual/multi-purpose crops
- Performance benefits in engineering composites
  - Lower weight and reduced fuel consumption (non-structural parts in cars)
  - Good thermal insulation (buildings, cars)
  - Good accident performance, less sharp edges (cf, metal, and glass/carbon fibres)
  - ...

CSIRO/OMSE. MengheMiao

Composite parts for automotive industry

Building materials

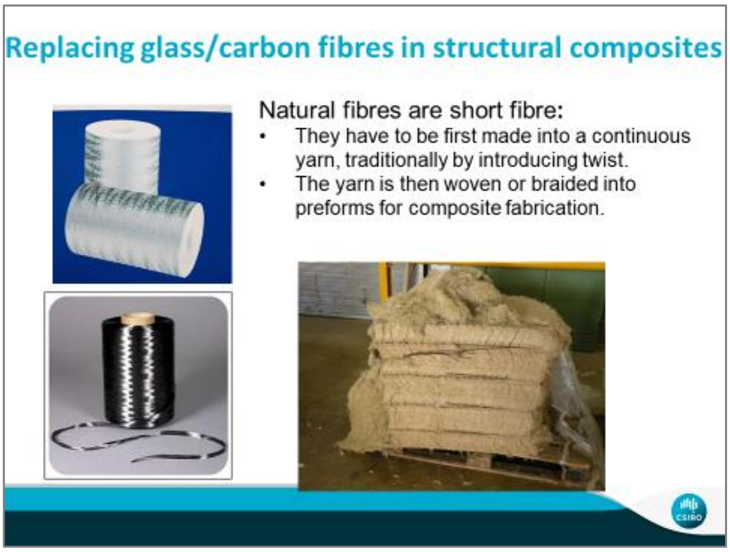
https://en.wikipedia.org/wiki/Hemp

Oil spill absorbent from hemp

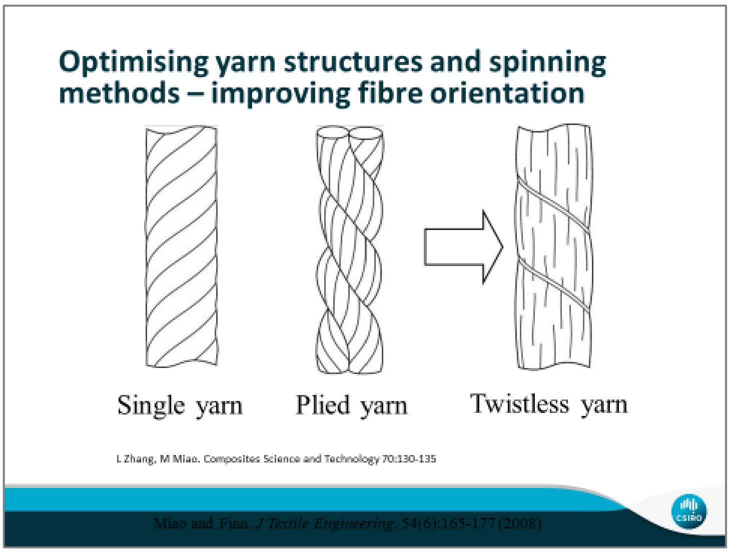
https://www.britannica.com/event/Deepwater-Horizon-oil-spill-of-2010

SpillMaster

http://hempinc.com/products/spill-be-gone-oil-spill-cleanup-product/

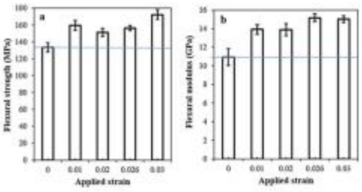

Replacing glass/carbon fibres in structural composites
Natural fibres are short fibre:
• They have to be first made into a continuous yarn, traditionally by introducing twist.
• The yarn is then woven or braided into preforms for composite fabrication.


Spinning and weaving of decorticated hemp fibres for use in structural composites
- CSIRO research supported by Composites CRC
16 | Presentation title | Presenter name


Optimising yarn structures and spinning methods – improving fibre orientation
Single yarn
Plied yarn
Twistless yarn
L Zhang, M Miao. Composites Science and Technology 70:130-135
Miao and Finn, J Textile Engineering, 54(6):165-177 (2008)

Prestressed natural fibre reinforced composites

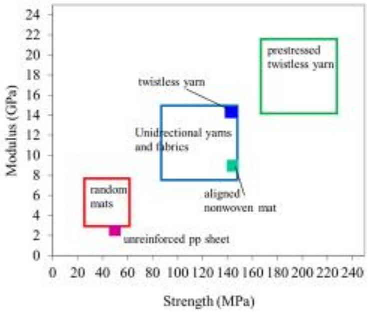
By Michael Schmahl - Own work, https://commons.wikimedia.org/w/index.php?curid=11140093



BM Zaidi, K Magniez, M Miao. Prestressed natural fibre spun yarn reinforced polymer-matrix composites. Composites Part A, 75:68-76 (2015)

Natural fibre-reinforced structural composites

CSIRO research supported by Composites CRC



Miao & Shan, Composites Sci & Technol; 71: 1713–1718 (2011)
L Zhang, M Miao. Composites Sci& Technol; 70:130-135 (2010)

Biodegradable shipping pallets

CSIRO – Biofiba project funded by AGP

Six billion export shipping pallets are produced & sold globally each year. Pallets are used only once then dumped into landfill.

Biodegradable weedmat

CSIRO project supported by RIRDC (AgriFutures Australia)

Thank you

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W: www.csiro.au/manufacturing

Investigation of wash behaviour of hemp-based denim substrate

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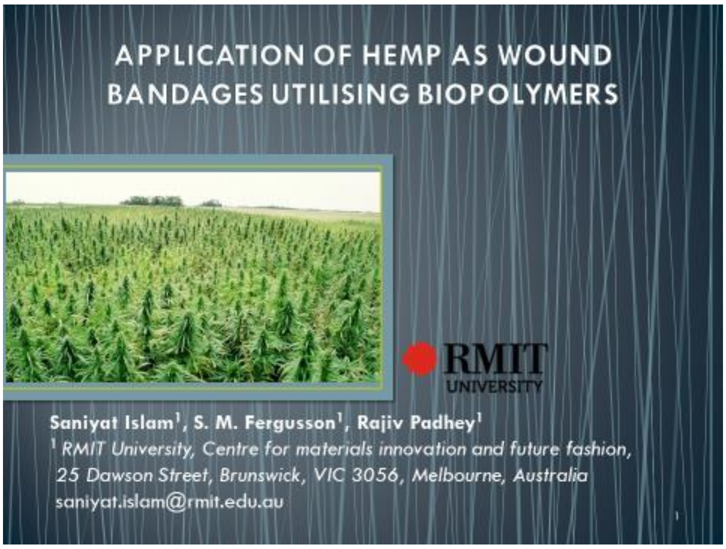
*saniyat.islam@rmit.edu.au

Keywords: Hemp, denim, colouration, washing, sustainability

Abstract

Denim washing has been looked into in great details in the recent years and emphasis has been given to a shift towards more sustainable and environmentally friendly washing methods as denim washing has been associated with usage of huge amount of water, energy and generating effluent on an industrial scale. The current study was focused into investigating the wash behaviour of hemp-based denim substrate. A series of experiments were conducted to assess the discolouration properties of commercially available enzyme-based wash chemicals. An ionic liquid based solvent was compared to the enzyme-based chemicals for improvement of discolouration properties. Ionic liquid was chosen for its ease of application as it is miscible with water in any ratio as well as can be recovered from the wash liquid which provides sustainability credential to the optimised wash process developed in this study. All the treated samples with different wash chemicals were tested for strength of colour over successive laundering cycles. It was found that the ionic liquid based washing was more effective in terms of discolouration of the hemp denim fabric compared to the commercially available enzyme wash chemicals. A significant improvement was to usage of less chemical dosage and time consumed with the reported washing process as it shows promise to be adopted into the denim wash houses industrially.



RMIT University

- Smart and functional Materials
- Age Care

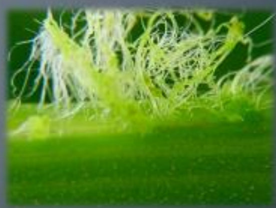
- Medical
- Defence
- Hygiene
- Comfort
- Sports

Centre for material innovation and future fashion

RMIT UNIVERSITY 2

Project Background

- RMIT Centre for material innovation and future fashion did a research project to utilise hemp fibre for Medical application such as dressing materials for its intrinsic beneficial properties such as high absorbency. The project was funded by Textile & Composites Australia Private Ltd and State Government of Victoria.



http://www.textilecomposite.com.au/index.html

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Decorticator Innovation

- TCI's unique and revolutionary process decorticates hemp stems and other bast crops while green or from dry sheaves, without the need for costly, damaging and time- consuming 'retting'.
- 'Retting' is a word derived from the Dutch word that means 'rotting'; until now, the process for separating fibre from the core has been via a rotting process of the crop that badly damages the crop and reduces the available fibre and hurd for commercial use by up to 80%.
- This is why hemp fibre has been so expensive compared to cotton and synthetic fibres, and why most hemp fibre has lost its natural strength, thereby restricting its use in composite materials.

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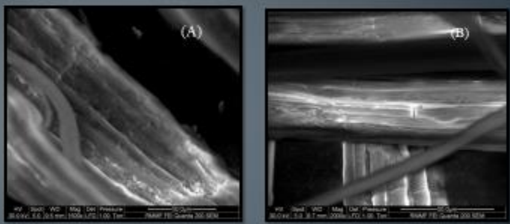
Conventional retting process for hemp
5


Decorticator
6


Research Idea
Figure 1 : Hemp fibres before (left) and after degumming process
The hemp supplied had to be further processed and a novel degumming process was developed for this project. The degummed hemp fibres can be seen in the figure compared to the decorticated fibres.
7

SEM



SEM images of raw (A) and degummed (B) hemp fibres

8

Considerations

To develop intended medical applications a nonwoven hemp and a covering material with 'Crabyon' Mesh were prepared as an ensemble. The swatches were treated with chitosan from crab shell with a simple pad-dry-cure process before the mesh was applied.

The developed materials were characterised for absorbency and antibacterial attributes.

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9

Materials

- Decorticated Hemp supplied by TCI
- Crabyon yarn sourced from China,
- Chitosan from Crab shells sourced from Sigma Aldrich

Machines for prototype preparation

- Integrated Card Cross-lapper (Make: Shoushiang China)
- NeddlePunch (Make: Shoushiang China)
- FAK Sample Knitting Machine
- Warner Mathis Pad Mangle (Make Switzerland)

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Fabrication of the dressing

The fabrication of the hemp-based dressing is shown in Figure 2.

Needled nonwoven | Crabyon Mesh | Dressing prototype

Figure 2: Fabrication of the dressing prototype

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Absorbency Testing

- The absorbency was tested by taking 1gm of sample in a petri dish and water or blood (defibrinated horse blood) were added drop by drop till saturated and the final weight was recorded. The samples were tested for at least 10 times and the average was calculated from the initial weight.

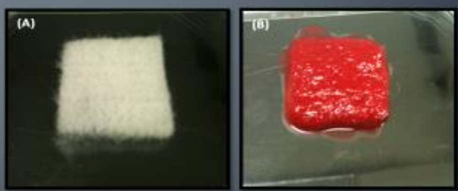

Figure 3 : (A) initial sample at dry condition (dry), (B) sample at saturated status

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Absorbency property

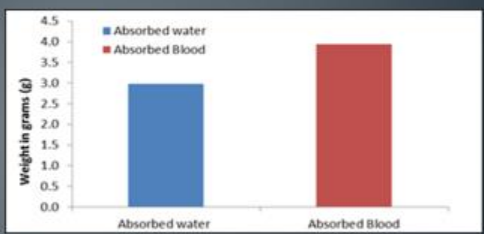

Figure 4: Comparison of the absorbency properties of the developed samples

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Antibacterial testing

- The antibacterial test was conducted with a modified AATCC 100-2004 (clause 10.2) test standard. Escherichia coli (E. coli) ATCC 11229, a gram negative bacterium, were used as the test specimen organism.

- The percentage reduction of the bacteria by the fabric specimen treatment was calculated with the following formula :

$$\text{Reduction in CFU\%} = \frac{(B-A)}{B} \times 100\% \qquad (1)$$

Where, B= average number of bacterial colony in untreated substrate
A= average number of bacterial colony in chitosan treated Hemp substrate

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Antibacterial Results

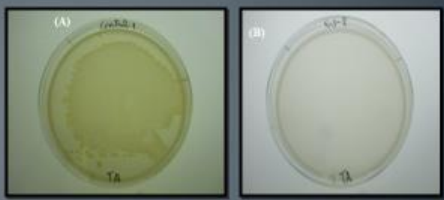

Figure 4 : (A) Control shows complete growth of bacteria; (B) Chitosan-treated hemp sample shows no growth

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Anti Mould Properties

- Mould is a type of fungi that lives on plant and animal matter. Mould grows best in damp and poorly ventilated areas, and reproduces by making spores. Airborne mould spores are commonly found in both indoor and outdoor environments.
- To replicate the growth of mould a laboratory test was done using milk and yeast as an additive for growth. 50 ml milk and 2 grams of yeast was added on two petri dishes containing a control (untreated) and a chitosan-treated hemp sample. The dishes were kept open in the laboratory atmosphere and were observed every day for growth of mould.

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Antimould Testing

Week 1 Week 2 Week 3

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Summary

- The study focused on exploring new avenues for hemp fibres.
- To substantiate that claim the project evaluated nonwoven hemp for application in medical products such as absorbent bandages or dressing materials. After overcoming the initial challenges with processing the raw material provided, key properties to assess are the absorbency and antimicrobial properties.
- To eliminate direct contact with the skin a skin contact layer was fabricated using crabyon yarn. The developed prototypes were tested for their absorbency, anti-mould and antibacterial properties.
- The results indicated that the developed prototypes were excellent in absorbing liquid such as water and blood absorbency attributes, it is envisaged that hemp could successfully be incorporated in dressing application in medical textiles.

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Washing behaviour of hemp-cotton denim

- Two commercially available enzymes were chosen to test the colour loss over successive washing of a hemp-cotton denim fabric sourced from Hemp gallery. The two enzymes are
  - Bezym (CHT) and
  - Washaway (Oxford Technologies).

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Washing procedure

- The material to liquour ratio was maintained to be 1:4 throughout all the experiments. An Atlas launderometer was used with 10 steel balls with 2% application of the products on the weight of the fabrics.
- Time of treatment was recorded to be 45 minutes for each wash and the temperature was maintained at 42±2^{0}C. After each wash the fabric samples were rinsed with cold water and then dried in a drying cabinet at 60^{0}C for 10 minutes before measuring the samples for loss of colour or the strength of colour using a spectrophotometer Colourquest and Colorlab+ (Premier Colorscan) software.
- The samples were tested 3 times and the results were recorded in comparison with the control sample that was not washed and used and measured as received from the fabric supplier.

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20

Effect of Bezym on successive washing

21

Effect of washaway on successive wash

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22

Findings

- The hemp-cotton blend denim was consistent for both the enzyme washes.
- The colour loss was gradual and the shade became blue to red over successive washes as expected.
- It was found that the tested fabric was not traditional ring dyed denim like cotton, however, was yarn dyed with reactive dyes instead of indigo.
- Work is in progress to achieve a green washing of denim using Ionic Liquid based application.

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thank you!

Dr Saniyat Islam

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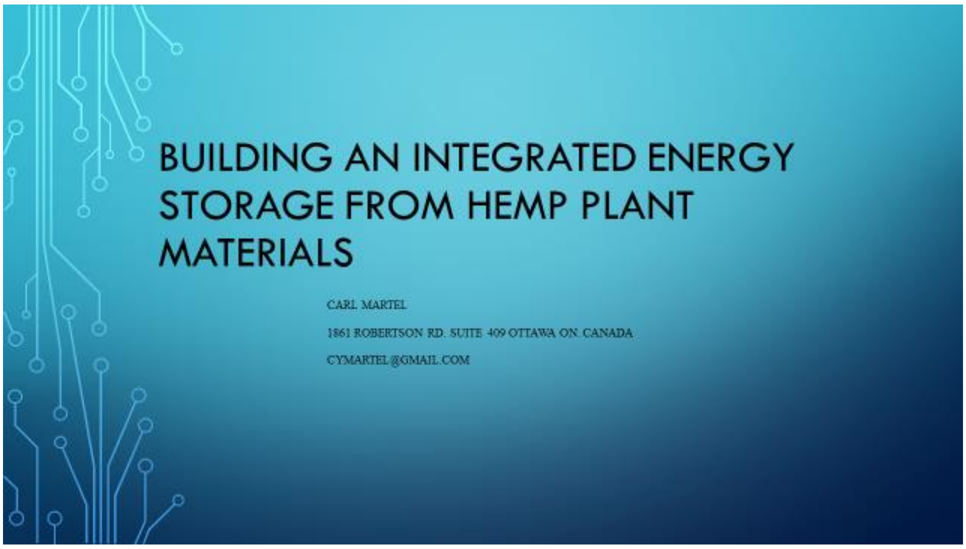
Building an integrated energy storage from hemp plant materials

Carl Martel,
Independent Scientist,
Alberta, Canada

cymartel@gmail.com



PLANT BASED CARBON

- Graphitic carbons have played an important role in electrochemical technologies.
- The type of carbon plays a major role in improving the performance of electrodes used in batteries and fuel cells.
- Plant based carbons via carbonization will play a vital role in future electrochemical technologies.

BUILDING INTEGRATED PHOTOVOLTAIC

WHAT IS BIPV?

BUILDING INTEGRATED ENERGY STORAGE

- What is BIES?
- The importance of surface area.

BATTERY SIZE COMPARISON

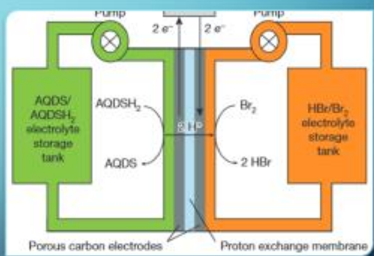
- Power requirements for house hold; 20kWh
- Lead-acid batteries energy density of 30 to 40Wh/kg; weight 450kg; size 1 x 1 x 0.3 metres
- Tesla Powerwall 2x10kWh; weight 200kg; size1.3 x 1.72 x 0.18 metres
- Vanadium flow batteries 10-20Wh/kg; weight 900-1800Kg; size 0.8-1.33m^3.

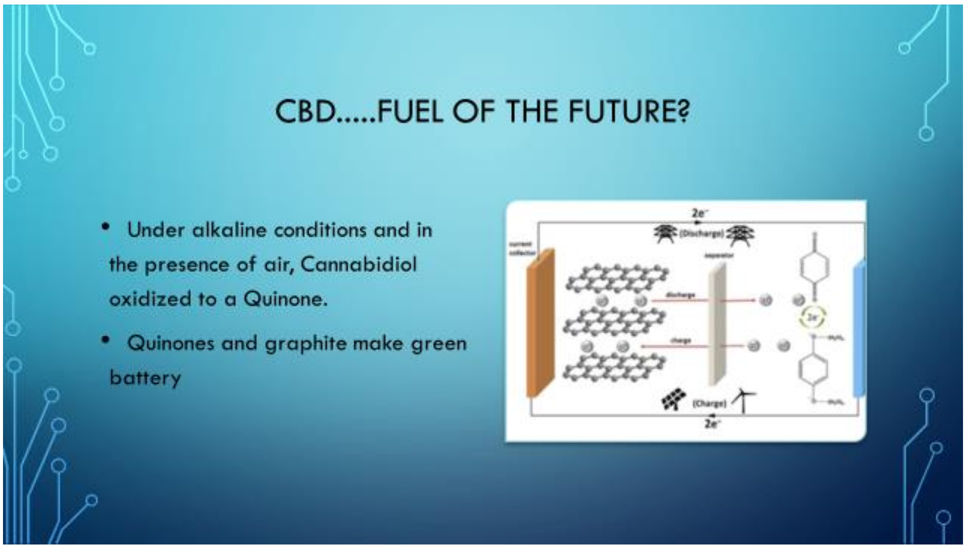
DUAL CARBON

- Cycle life and surface area
- Cheap non-toxic materials

FLOW BATTERIES

- Flow battery
- Quinones in nature play a vital role in the biological electron-transfer process, such as photosynthesis.
- What do Quinones have to do with Hemp?




CBD.....FUEL OF THE FUTURE?
• Under alkaline conditions and in the presence of air, Cannabidiol oxidized to a Quinone.
• Quinones and graphite make green battery


WHAT I DO

Hemp Processing and the Australian Hemp Construction Industry[2]

Klara Marosszeky,
PO Box 1059,
Lismore, NSW 2480

kmarosszeky@gmail.com

Abstract
Despite Australia's early history of hemp farming, the hemp construction industry in Australia essentially developed without there being any other substantial commercial application for hemp fibre in Australia. This differs from Europe where bulk processing for hemp bio-composites for the automobile industry and animal bedding has been established for many years and primarily governs the way that the majority of hemp is processed. Prior to that hemp paper manufacturing was relatively commonplace in Europe and prevalent in France, so despite widespread prohibition, there was an availability of hemp hurd or shiv for the French housing industry to be established in the 1980's and for volume construction to be considered.

As a result of the absence of any sophisticated Australian hemp industry, when we began researching the development of building materials at UNSW in 2000, what was available to us was very coarsely processed Australian hurd that was being produced for mulch. A mini-processor was built at the university and we began to examine the characteristics and performance of hemp processed in multiple forms from pulverized flours to larger, evenly chopped material including chopped whole stem hemp, to examine the performance characteristics of various mixes and materials for use in construction.

An overarching research goal was to examine the carbon implications of the materials we were developing. Whatever we arrived at needed to maximize thermal and acoustic performance, remain breathable and retain non-flammability and if possible the embodied energy and materials intensity of any products we developed needed to be reduced. In a sense Australia back then, offered an opportunity to re-examine hemp construction.

Despite identifying an optimal specification for hemp for housing that could create a material matrix that supported lower use of mined materials in the binder, getting to the point where hurd material to this specification was reliably and readily available took until early 2017 with the opening of the Dungog Hemp Mill in the NSW Hunter Valley. Suitably processed hemp hurd had been available earlier in 2010 from a small farm in Ashford in the NSW Tablelands, however the farmers did not have the finances to upscale their prototype processing plant. During the intervening years there was quite a lot of reconfiguration of our original blend necessary as we worked with farmers to investigate different small to medium scale processing options and contended with materials that were less than ideal for building.

---
[2] Klara Marosszeky was a late apology from the Conference Program. Glen Ossy-Orley, a hemp grower/builder from Nannup in WA, kindly provided an oral presentation on building with hemp as the replacement presenter.

Thursday, 1 March 2018

SESSION 8
Final plenary – the market value for hemp products

Chair: Andrew Davidson, CEO, Midlands NZ

REPORT FROM THE INDUSTRIAL HEMP REGULATORS MEETING
Mike Davies, Department of Primary Industry and Regional Development

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Preserving seed quality on farm for consumers
Jeff Kostuik, HGI, Canada

Hemp seed for human consumption - consumer insights
Anthony Saliba, Charles Sturt University, NSW

Hemp global markets
Paul Benhaim, Elixinol Global Limited, NSW Australia

The value in hemp fibre
Mark Reinders, European Industrial Hemp Association, Germany

The value of hemp shiv for building
Kirstie Wulf, Shelter Building Design, Hazelbrook NSW

Hemp products into the future
Phil Warner, Ecofibre Australia, QLD

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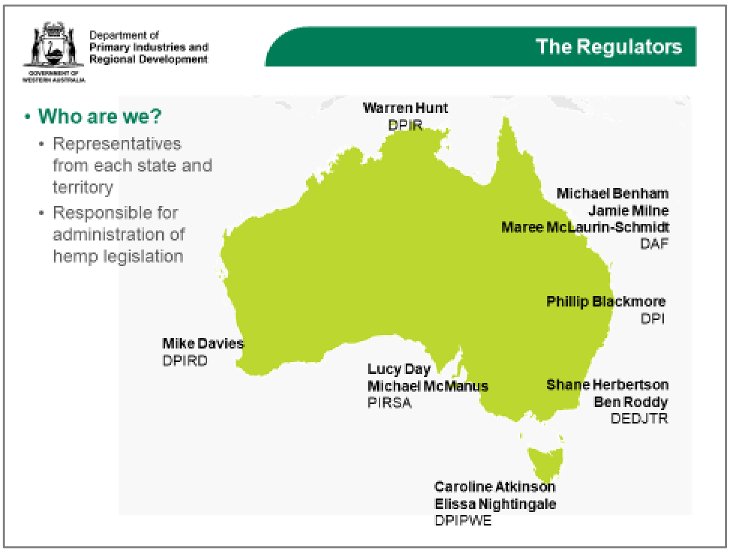
MIDLANDS

REPORT FROM THE INDUSTRIAL HEMP REGULATORS MEETING

Mike Davies,
Department of Primary Industry and Regional Development,
Government of Western Australia



Department of
Primary Industries and
Regional Development

When, Where and Why

- Inaugural meeting held Tuesday 27th Feb 2018
- Held at Geelong State Government Offices
- Collaboration
  - To establish a national network of hemp regulators to facilitate knowledge sharing
  - To investigate opportunities for harmonisation across jurisdictions to support industry development
  - Act as a forum to capture opportunities for policy development

Department of
Primary Industries and
Regional Development

Where to from here?

- Australian Industrial Hemp Regulators Working Group
  - Formalise group
- Meet
  - Group has agreed to continue to meet annually and on an as needs basis as issues arise
- Sampling protocols
  - A key outcome of the meeting is for the group to review individual jurisdictional sampling protocols for consistency and benchmark internationally
  - National maximum THC levels were discussed
  - Laboratory analysis services were discussed and opportunities to further investigate, qualification, turnaround times and geographical considerations
- Collaborate
  - The AIHRWG expresses its willingness to engage in the future with a peak industry body

Department of
Primary Industries and
Regional Development

Thank you

Visit dpird.wa.gov.au

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Preserving seed quality on farm for consumers

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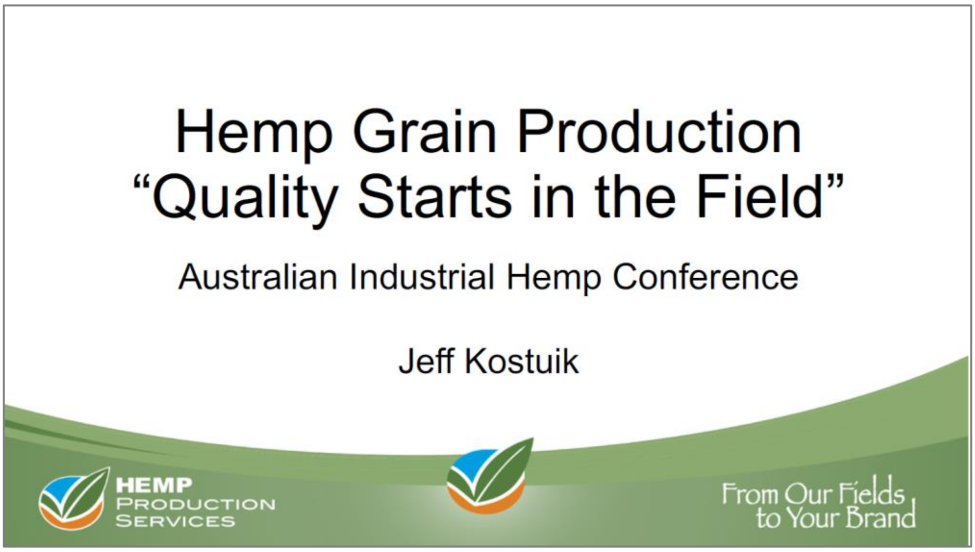

Microbiological Limits

Peroxide Value	Less than 4 meq/kg
Standard Plate Count	<100,000 CFU/g
Total Coliforms	<1000 CFU/g
Fecal Coliforms	Negative=LOD<10CFU/g
E. coli	Negative=LOD<10CFU/g
Salmonella	Negative
Staphylococcus A	Negative
Mold & Yeast	<1000CFU/g
Gluten	Less than 20ppm
THC	Less than 10ppm
Pesticide Residue	Nil

HEMP PRODUCTION SERVICES From Our Fields to Your Brand HGI HEMP GENETICS International

Producing Quality Hemp Products

- What is the market demanding?
- How can you supply quality hemp?
- Systematic approach is required to maximize quality;
  1. Proper Planning
  2. Agronomics,
  3. Harvest & Storage Practices.

HEMP PRODUCTION SERVICES From Our Fields to Your Brand HGI HEMP GENETICS International

Seeding

- Seed Shallow - ~ ½ inch
- 20-25 lbs/acre seeding rate for grain
- Higher seeding rate for Fibre
- Warm Soils – above 8 – 10 degrees C
- Equipment – Low fan speed for air seeders

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Seeding rate

- Plant population
- Higher seeding rates may lower yield due to promoting long internodes and suppressed branching
- Hemp (single stalk annual) suppress later branching when grown in thick stands

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HGI HEMP GENETICS International

Fertility

- Hemp responds well to N, P, K and S when soil nutrients are low

	Total Plant (Kg.ha)		Grain (Kg/ha)		Uptake
Nutrient	Hemp	Canola	Hemp	Canola	Hemp/day
N	200	120	40	65	6.7
P	47	50	19	35	1.56
K	211	75	10	17	6
S	14	20	3	12	

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Disease - Sclerotinia

HEMP PRODUCTION SERVICES

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Harvest Management

- Timing of Harvest
- 10 to 20% moisture
- Cracking
- Frost
- Dry to below 10% for safe storage

HEMP PRODUCTION SERVICES

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Straight Combining

Goal : Smooth uniform feeding

Problems:

- Fibers wrapping on moving parts

Solutions:

- Correct Timing!!
- New Combines – Few Modifications
- NEW knife and guards
- Draper headers best

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Storage & Handling

Prevent Contamination

- Clean harvest and handling equipment
- Clean out the bins
- Eliminate opportunities for rodents, birds, and other pests

Prevent Spoilage & Monitor

- Invest in moisture cables


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HEMP PRODUCTION SERVICES
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Drying

#1 priority is to dry the hemp to <9%

- Dry Low + Slow to avoid toasting the hemp

Factors for bacterial & mold growth

- Time
- Temperature
- Moisture

Higher moisture + Higher temperatures = Ideal conditions conducive for development of bacteria and molds

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HEMP PRODUCTION SERVICES

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Hemp seed for human consumption – consumer insights

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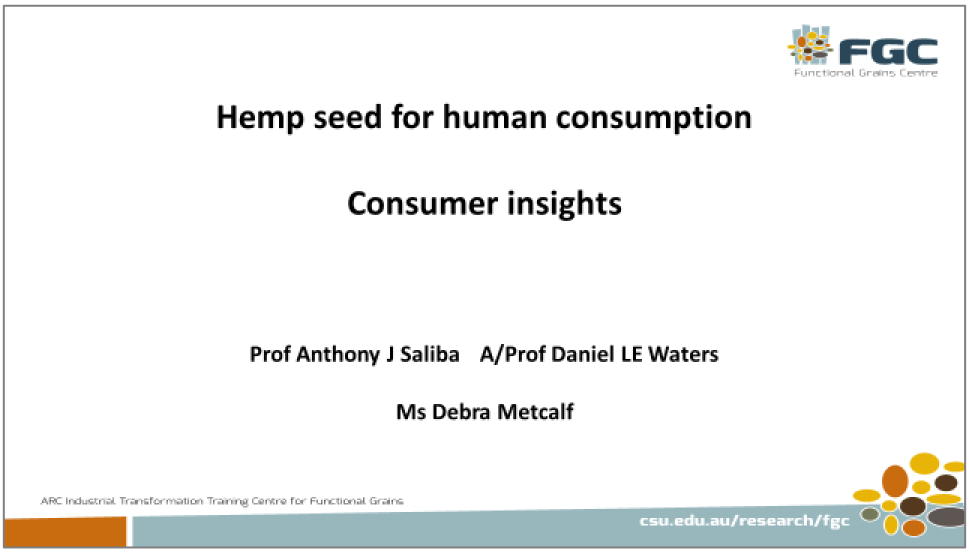
Keywords: Hemp seed, consumer, adoption, marketing, consumption.

Abstract

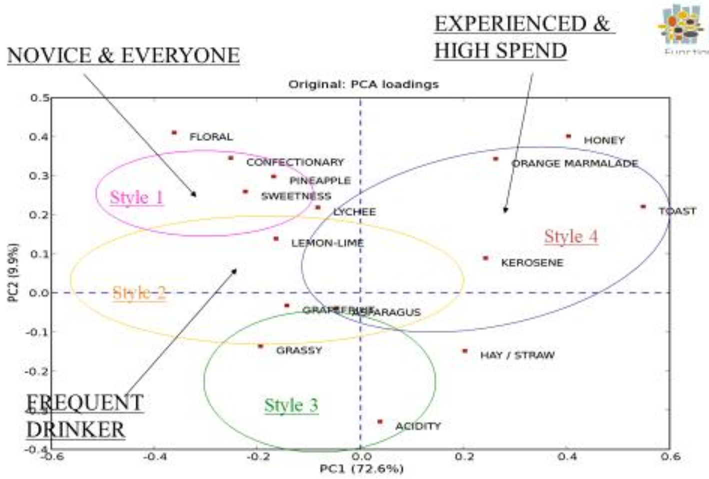
The seed of hemp (*Cannabis sativa*), consumed by humans for millennia, have positive human health benefits beyond supply of simple nutrients. The positive features of hemp seed composition include high oil and protein content, both of which approach 30% in selected genotypes. Hemp seed oil has both a high concentration and an unusually well balanced mixture of the essential fatty acids linoleic and linolenic acid while hemp seed protein is primarily composed of highly digestible albumins and globulins, both of which have a favourable amino acid profile. Enzymatic cleavage of hemp proteins generate peptides with antioxidant activity and blood pressure reduction properties. Beyond protein and lipid, hemp seeds contain high concentrations of tocopherols, compounds with antioxidant activity, high concentrations of the anxiety reducing cannabidiol (CBD) and low concentrations of the anti-nutritional compounds, phytate, tannin and typsin inhibitors.

Using traditional adoption models, the positive human health attributes of hemp seed suggest that hemp seed has the potential to become a valuable new food crop for Australia. However, there are multiple factors unique to hemp seed that violate assumptions made by traditional food adoption models. We discuss those unique factors and suggest a way to navigate the complex adoption issues from both a prediction and marketing viewpoint.

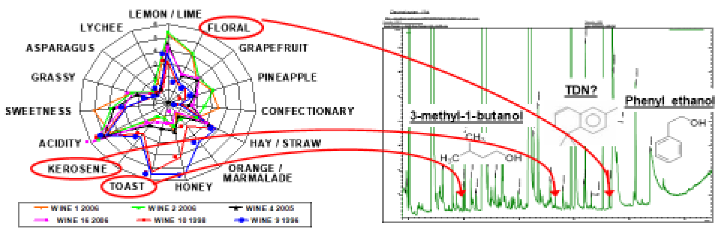


Past Research

- Multi-disciplinary
- Hunter Valley Semillon
- Highly awarded wine
- Sales not commensurate with quality



Sensory profile **Chemical analysis**



Uses for hemp *(Australia)*

Spoilt for choice:-

- Fibre with utility in vast array of products
- Highly efficacious medicinal properties
- Highly nutritious human food

Attributes of hemp seed for human consumption

Again, spoilt for choice:-

- High content of digestible and nutritious protein
- High content of nutritious lipids
- Antioxidant tocopherols
- Anti-anxiety properties (CBD)

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csu.edu.au/research/fgc

Hemp seed and rice co-domestication; a great story

- New blended rice products
- Rice and hemp seed are complementary; rice is high starch low protein low lipid while cannabis is low starch high protein high lipid content
- Rice and hemp seed both domesticated in Asia

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csu.edu.au/research/fgc

Hemp seed baggage

FGC Functional Grains Centre

- Community attitudes and perceptions shaped by years of negative press
- Non-linear attitudes, individual differences
  Generational cohort

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csu.edu.au/research/fgc

Cultural Specificity

FGC Functional Grains Centre

- Hemp consumed in other countries
- Australia somewhat unique in terms of adoption (e.g. health)
- Australia very unique in terms of perceptions of hemp

Conclusion: may not be accurate to extrapolate adoption from other countries

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csu.edu.au/research/fgc

Predicting Food Choices

FGC Functional Grains Centre

- Models of adoption and choice are available
- Some unknowns can be modelled through Psychographics*
- Models rely on the food having 'normal' properties
- Will they help with hemp ?

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Steptoe et al. model

- Steptoe, Pollard & Wardle (1995); Appetite, 25, 267-284.
- Has been updated, we use an adapted model in consulting

9-Factor model

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Steptoe et al. model

- Factor 1 – Health (6)*
  - 22. Contains a lot of vitamins and minerals
  - 29. Keeps me healthy
  - 10. Is nutritious
  - 27. Is high in protein
  - 30. Is good for my skin/teeth/hair/nails etc
  - 9. Is high in fibre and roughage
- Factor 2 – Mood (6)
  - e.g. 16. Helps me cope with stress

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Steptoe et al. model

- Factor 3 – Convenience (5)
  - e.g. 1. Is easy to prepare
- Factor 4 – Sensory Appeal (4)
  - e.g. 14. Smells nice
- Factor 5 – Natural Content (3)
  - e.g. 2. Contains no additives
- Factor 6 – Price (3)
  - e.g. 6. Is not expensive

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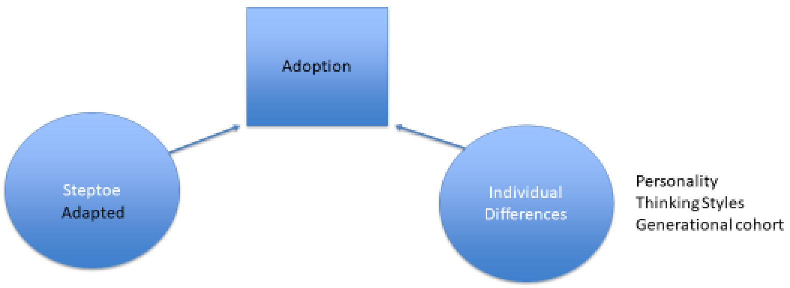
Steptoe et al. model

- Factor 7 – Weight Control (3)
  - e.g. 3. Is low in calories
- Factor 8 – Familiarity (3)*
  - 33. Is what I usually eat
  - 8. Is familiar
  - 21. Is like the food I ate when I was a child
- Factor 9 – Ethical Concern (3)*
  - 20. Comes from countries I approve of politically
  - 32. Has the country of origin clearly marked
  - 19. Is packaged in an environmentally friendly way

Research Question



Conclusion ?

- Good consumer insights research is required, soon
- Marketing can be used to influence attitudes and awareness
  Need to understand attitudes (also individual differences)
- PhD student looking into some of these issues (watch this space)

Prediction: *the market size and shape will be related to our understanding of consumer attitudes.*

Hemp and Cannabis Global Markets

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Keywords: Hemp Foods, Medicinal Cannabis, CBD, Elixinol Global, Industrial Hemp

Abstract
To assess the global markets for cannabis – including industrial hemp and medical cannabis. Considering global companies, market data and experiences. Through this study it was noted the cannabis market is growing and there continues to be potential for significant growth in this sector.

Introduction
The opportunities for hemp and cannabis are seemingly endless, with both very positive and sometimes highly confusing reports by the media. Separating fact from fiction is not always easy. This paper was written to offer a global overview.

Having studied hemp from history books and literature such as Jack Herer's book The Emperor Wears No Clothes, the Author created the UK's first commercial hemp food product in 1993. And since that time consulting to and working with various companies, some of whom represent the most successful cannabis and hemp businesses of today. In 1999 the Author immigrated to Australia to bring the knowledge of hemp foods to the country. Despite the challenges and time delays, hemp seed as a food was legalised in Australia late in 2017. Before this, in 2012 the Author had the foresight to invest in a production facility, via a business named Hemp Foods Australia, in New South Wales to produce hemp seeds, oil, protein and flour 'not for human consumption'. Hemp Foods Australia is now the largest organic hemp foods manufacturer in the Southern Hemisphere.

Following this, in 2014 the Author co-founded Elixinol LLC in Colorado, USA as the legislation in Australia was not supportive of this business' intention. According to Forbes, Elixinol LLC (USA) is today one of the largest brands and businesses in the CBD (cannabidiol) nutraceutical market in the world. Furthermore, when Australia allowed medicinal cannabis cultivation, manufacturing and distribution to be licensed, Elixinol Pty Ltd was founded with the intention to enter this industry. This medicinal cannabis startup became the third entity to be acquired by Elixinol Global as it entered the Public Markets.

Elixinol Global (ASX: EXL) acquired three business to start – Elixinol LLC (USA), Hemp Foods Australia and Elixinol Pty Ltd (Australia). It is through the last 25 years your Author has come to know and grow with some of the best people in the industry. This has assisted Elixinol Global and its subsidiaries in distributing products in 40 countries with annual revenues expected to exceed over $15m in 2017, on a strong growth curve and with virtually no debt. It is through these decades of experience that the subject matter in this matter was considered important and worth sharing for analysis and future growth.

What is Hemp and Cannabis?
The terms hemp and cannabis are often confused. What about medicinal cannabis, recreational cannabis, marijuana, industrial hemp and the myriad of other terms that are used to describe many aspects of one plant? Cannabis is the latin name for a plant with many names. From there, life can get complicated – *Cannabis sativa*, *indica* or *ruderalis*? There are detailed books written on this

subject alone. In general, from a legal and laymans perspective there are two main types of cannabis that we should be practically concerned about in the global markets. One form of cannabis contains low amounts of delta-9-tetrahydrocannabinol – or THC for short, the other contains higher amounts of THC. THC is the ingredient in Cannabis that is said to 'get you high'. The psychoactive abilities of THC are well known. Most countries legally define the difference between 'industrial hemp' (or hemp) and 'medical cannabis' (or marijuana or recreational cannabis or ganja) based upon the content of THC. To confuse matters more – the amount of THC that is used to define this difference varies from country to country. And, in Australia as an example this differs from state to state. Globally the quantum for cut-off – the difference between industrial hemp and medical cannabis is between 0.2% and 1%. In the authors view, 1% seems the most natural as it seems to be the recognised stable level often found wild in nature. Most of the world (Europe, North America) uses 0.2% or 0.3% - which has caused challenges for seed breeders and farmers world-wide in ensuring their THC limits meet the regulatory standards. Whilst the focus from a legal standpoint has been on THC, THC is simply one of many hundreds of constituents including various cannabinoids, terpenes and flavonoids known to exist in the cannabis plant. Although research is ongoing, it is clear there are two main cannabinoids that are by far the predominant active ingredients in cannabis – they are THC, as described, and cannabidiol, or CBD for short. CBD, although proven to not get 'you high' has been shown to have very interesting opportunities in the medical community. The grass roots 'word of mouth' interest seems to have grown significantly, whilst research – moving at a slower pace struggles to keep up.

One of the reasons CBD or medicinal cannabis or nutraceutical/ dietary supplement forms of this product (usually sourced from industrial hemp to complicate matters) has become successful is that no research has proven direct harm from overdosing or taking significantly larger doses that is usual. Many argue that due to non-harm paired with the fact that there are many anecdotal cases of seemingly miraculous results from this product, that it should be used commonly. This author believes that allowing non-psychoactive CBD products to be used in food – to be a basic ingredient for all to use may benefit our society greater than we yet know. The Australian Government does not seem to agree as in 2017 the Ministry of Health ensured CBD products were considered in the 'same basket' as medicinal cannabis or high THC cannabis. This unusual approach has significantly slowed and restricted both the industry and more importantly, the access of this product for patients that may otherwise benefit significantly. This may have created another under-ground market. The author wonders if that is what the Government intended.

Although the THC content of industrial hemp or medical cannabis seems the most important to legislators, there are other properties of the cannabis plant that matter more to industry. Unless of course, you are producing for THC. The cannabis plant has a strong root system, a tall stem with fibre and shivs (hurd), abundance of leaves that may produce flower and seeds. Roots, fibres, shiv, leaves, flower and seed are all the raw ingredients for multiple uses within multiple industries. It is why hemp is purported to have '50,000 uses'. In practice there are only some industries that use hemp today in any quantity, and maybe a few others that are growing. We shall explore these. The physical, visible difference between a cannabis plant grown for THC and a plant grown for food and a plant grown for fibre is significant. Some plants grow only 1 metre high (for food), some are very thin but 5 metres tall (for fibre) and some are 2 metres wide (for flowers).

Hemp Farming

A total land area of approximately 120,000ha was used in 2016 for growing industrial hemp alone [1], with China leading the pack at 42% of global crops. China has a long history of growing hemp and has been a mainstay of their economy for many years. In the mountainous regions of China hemp is grown sustainably in small villages who mainly supply a local collector who cleans and sorts the crops ready for sale. This is quite different to the Canadians who grow nearly 30% of the world's industrial hemp crop as a mono-culture in very large fields. Australia was not in the top 10 hemp growing countries in 2016.

Growing nearly as much as China (and some say they have now overtaken), the acres Canada has grown increased significantly since 2008. 2014 was a lesson for Canada when some farmers thought they would join the cash cow, and found that there was an oversupply in the market. This led to a major correction in 2015 and 2016 – affecting some farmers significantly. The lesson learnt was to follow the market. Will other countries, like Australia make a similar mistake?

The European Union grew 33,000 ha in that same year, 2016 with France being by far the largest grower of cannabis in the EU [2]. The USA has now started to grow industrial hemp, with the biggest states including Colorado and Kentucky. In the USA, like much of the world – the choice for organic foods has increased. From 2003-2014 there was a 10% compounded annual growth rate in sales of US organic foods [3]. This is expected to continue growing. Though there seems to be a ceiling. The growth of organic acreage in the US is growing at a far slower rate than the growth of organic sales [4]. So, although industrial hemp or cannabis is known for being a crop that 'grows like a weed', it seems in the home of Monsanto- the USA, this maybe due to the amount of chemicals they use in farming. As an example, Kentucky which grew a significant 12,800 acres of industrial hemp in 2017 is one of those places. Kentucky is known for 99.9% of its agricultural land being chemically driven [5]. Moving from that much chemical filled land into a crop that maybe used for food or medicine seems fraught with danger. This Author sees the consumer demand for hemp or cannabis grown with pesticides, herbicides and chemical fertilizers being fraught with risk. And it seems Australia is little different, most of the industrial hemp crops grown in Australia are grown on land that has not been certified organic or controlled for chemicals, and such industrial hemp crops continue to be grown with chemicals or herbicides or pesticides of some sort. The growth of independently certified organic or sustainable land would seem worth investing more focus on due to the increase in demand by consumers – if not for the sustainability and potential health benefits of not consuming chemical residues for such farming methods.

Hemp Foods

The use of hemp as a food goes back as far as history records go. Though modern commercial hemp foods only started around the 1990's it is only in the last few years that the growth of hemp seeds has been seen [6]. Europe sees 50% of the use of hemp seeds as organic. Some are grown in Europe, the rest in China. Lately it seems the Canadians are expanding into the European market also. In 2013, out of the 11,500 tons of European production of hemp seeds – 13% was used for hemp oil production, 43% for food and interestingly the majority - 44% as animal feed [7]. Although the animal feed market for hemp has been stable for the past decade, the human food market has been increasing.

Medicinal Cannabis

The Europeans also have an interest in medical cannabis, though data is sparse – there was a growth of the use of hemp flowers and leaves for CBD as a food/ nutritional supplement from 7.5 tonnes in 2010 to 240 tonnes in 2013 [8]. That quantity has significantly grown since then. The potential market for cannabis within the European Union (population 739 million) is expected to grow to around US$69b, with a majority of that used for medical cannabis [9]. In comparison, the industrial hemp market is worth closer to US$60m [10]. It is noted that in the European Union it is estimated 12% use cannabis of some form today [11]. In the USA, the market for adult/ recreational use of cannabis today is around $2.5b with medical cannabis worth $5.6b. The growth of recreational cannabis is expected to outpace medical by growing to $14.9b in 2021 in comparison to medical, expected to reach $7.7b in the same time frame [12]. In Canada the medical cannabis market is just $300m compared to the recreational market expected to be between $5-8.7bn [13].

There seems good economic reason, as well as potential health benefits for countries considering the legal recreational use of a plant that has been used for such in most places worldwide, and for centuries. Currently there are NO registered cannabis drugs approved by the FDA in the USA, though this is expected to change shortly with GW Pharmaceutical's Sativex. Sativex is one of four registered cannabis medicines allowed in Europe today.

Industrial Hemp Market

With less global data available, it is clear from Google™ searches that there has been a steep growth in searches for CBD which overtook searches for hemp recently. Google™ also shares with us the search terms for both hemp and cannabidiol (CBD) in clinical research papers – for which there has been a steep growth in the last few years [14]. The market for industrial hemp, although smaller than medical cannabis, is also growing. This is in part due to natural fibre prices increasing since 2011 [15]. This has opened up the automotive industry to industrial cannabis who (in 2013) consumed 14% of the 25,000 tonnes of hemp fibre harvested in the European Union. The largest use of hemp fibres continues to be for pulp and paper – mainly cigarette papers, produced in Spain and France. This makes up 57% of the use of hemp fibres today with building insulation, bioplastics and clothing more niche markets [16].

The inner core, or shivs sometimes known as hurd of the hemp stem is mainly (45%) used for animal bedding (horses). Other uses include construction (16%) and garden mulch (19%) [17]. Canada has shown that most of their industrial hemp has been used for grain, and that grain is predominantly exported to the USA – over C$120m worth in 2016 [18]. Due to a growing demand, and supply not quite catching up in 2016 the price of hemp seeds in Europe and the world increased. This dropped at the end of harvest season in 2017 when both the Canadians and Chinese, the two largest producing countries grew an oversupply. Though with a growth rate of over 20% in the global hemp based foods market [19], this may stable out over time. It is believed that the global hemp foods market was worth around $215m in 2015 [20], or just 0.03% of the total global market for food sales. The expected value of the market is expected to grow to $543m in 2020 and with many companies attempting to enter this field is expected to be a highly competitive market for this potential growth.

Public Markets

In Canada, the growth of Cannabis stocks on the TSX, especially in the last 3 months has been high with market cap of over $24.27bn. In Australia the growth has been over the last 12 months with many listed entities without any revenue being valued at tens of millions of dollars. Some say this is a bubble, others say this industry is likely to outpace the market. Only time will tell how well Cannabis does in the Public Markets.

Conclusion

Cannabis has been used as far back as history records go – for everything from paper to textiles. The modern cannabis industry consists predominantly of medical and recreational cannabis, with the industrial hemp foods market following. The more recent support by the Public Markets is likely to see further investment in this field and may finally see the use of hemp fibres and shivs expand into and beyond the automotive industry and animal bedding market. The author looks forward to reporting on these updates in the future.

Acknowledgements

Those in the global hemp industry who have worked tirelessly for decades with little return. May we all grow abundantly as our chosen plant.

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The Value in Hemp Fibre

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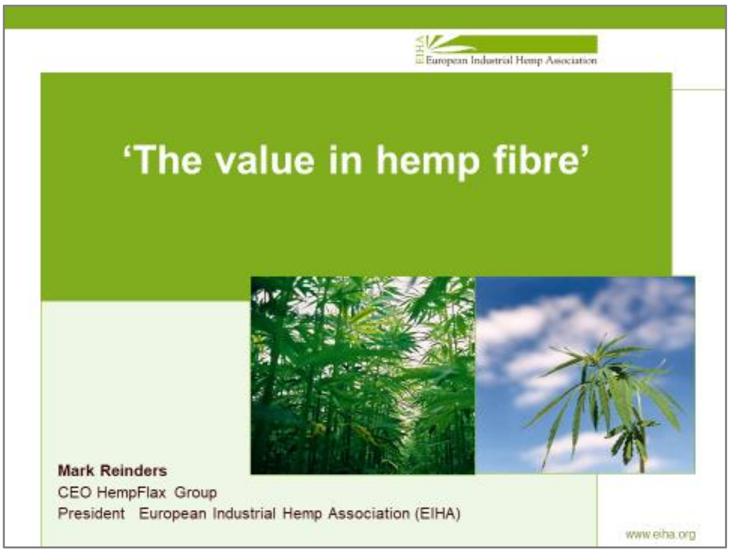

EIHA European Industrial Hemp Association

Quality influencers

- **Varieties**
  - Processability
  - Retting
  - Lignine content
- **Agricultural practices**
  - Sowing density
  - Harvesting moment and retting procedure
  - Fertilization
  - Harvesting technology
- **Techology**
  - Decortication lines/technologies
  - Skills of operators
  - Operational management
  - Quality management

www.eiha.org

EIHA European Industrial Hemp Association

Quality starts in the field!!

www.eiha.org

Growing

EIHA European Industrial Hemp Association

- Sowing April/May with regular sowing machines with small adaptations
- EU varieties <0.2% THC
- Animal origin manure
- 120-80-140 Nitrate Phosphate Potassium
- Growing speed : 4 cm a day
- **No Pesticides (organic and conventional)**
- **Romania 140 ha organic, rest no use of pesticides in last years**

www.eiha.org

Harvesting

European Industrial Hemp Association

- Double cut combine
  - Seeds
  - Flower & leaves
  - Stalks
- Hempcut patent HF
- GPS autopilot
- Cutting length 70 cm
- Released in a swath

Movie

02/05/2018 6

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Harvest

European Industrial Hemp Association

- Turning
- Baling
- Logistics

02/05/2018 7

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European Industrial Hemp Association

Hemp Processing
HempFlax (Alba, Romania 2016)

Hemp processing plant, HempFlax 2016

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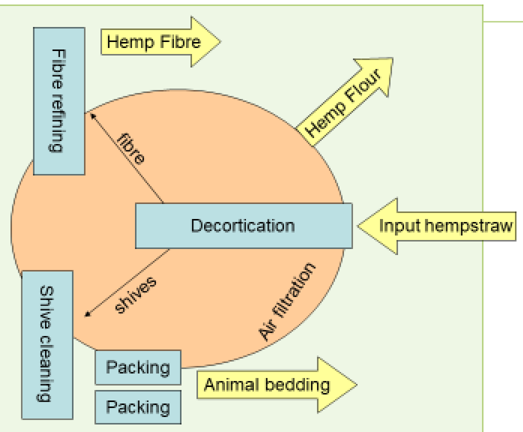
Fibre production

EIHA European Industrial Hemp Association



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EIHA European Industrial Hemp Association

Thank you for your attention.

QUESTIONS?

www.eiha.org

The value of hemp shiv for building

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Introduction

Since ancient times hemp has been known as a useful fibre for rope, paper and textiles. It is less known that hemp was used in building. At the Ellora caves in India, built in the 6th Century CE, hemp fibre, clay and lime were used in the wall plaster. It was found that the walls in the caves plastered with hemp were better preserved than in other caves[1].

Japan also has a long history of growing and using hemp including in Shinto and Buddhist rituals. In Miasa, an old hemp growing area of Japan, there is a house built in 1698 that used hemp in its construction. This building is now over 300 years old[2].

Modern hemp building uses the hemp shiv or hurd which is the woody fibre inside the stem. The hemp shiv is in fact a by-product of fibre production. So, hemp building creates a market for another part of the hemp plant, increasing the value of the crop.

The use of hemp shiv in the modern form we use today, mixed with lime, was first used in France in the late 1986 by Charles Rasetti to renovate *Maison de La Turque* a historic half-timbered house in Nogent sur Seine, France[3]. The hemp walls replaced the traditional wattle and daub but had a higher insulation value. The hemp lime walls maintained the vapour permeability of the walls unlike cement products that had proved unsuitable to repair such historic buildings.

Yves Kuhn continued the use of hemp in historic buildings such as Maison dAdam and as the product worked well in historic buildings he adapted it for use in new builds. Architect Ralph Carpenter was the first to use hemp in building in the UK[4] and in 2001 two townhouses out of a larger townhouse development at Haverhill, Suffolk UK, were made with hemp and studied by the BRE[5].

With changes to legislation in Australia in relation to industrial hemp production, interest grew in hemp building in Australia. Although, one of the first hemp houses in Australia, at Table Cape, in Tasmania was built using imported materials it showed that comfortable modern Council approved houses could be built in Australia. Owner, Roger Bodley, chose to create a total envelope of hemp, with hemp used under the floor, for the walls and as ceiling insulation.

I am passionate about building with natural materials and had worked with mudbrick and strawbale, but when doing research on the materials to use for my own house I came across an article on hemp building in Owner Builder magazine about the work being done by the Australian Hemp Masonry Company. I was intrigued by the qualities of the material and the ease of building. I did further research which convinced me that hemp/lime was the appropriate material for my build. So, my family and I spent many weekends building our hemp house. The house is beautiful to live in and requires no heating or cooling all year round. This is because of a combination of the hemp walls and good solar passive design.

Why build with hemp?

Some building products insulate- they stop heat going in or out. Some building products have thermal mass – they can store heat or cool and even out fluctuations in temperature. Hemp walls can do both, producing a thermally efficient wall. The Marks and Spencer store at Cheshire Oaks in the UK was the first large scale use of hemp on a retail development. In the UK it lost less than 1% of its heat overnight in winter, compared to 9% in other stores. The performance of the building was better than expected and even outperformed the designers estimates.[6]

Hemp walls are hygroscopic, meaning that they can adsorb and rerelease water vapour. This allows them to act as a buffer to humidity, taking moisture from or rereleasing it to the air. This process also stabilises the buildings internal temperature through the latent heat effect – energy is consumed and released during evaporation and condensation within the pores of the building[7, 8].

Condensation in the building fabric and how to deal with it appropriately is a substantial issue in construction in Australia where we sometimes heat our houses and sometimes cool them. The vapour permeability of hemp walls allows moisture to migrate outwards and not build up inside the building or in the building fabric.

Stable temperature was one of the reasons why The Wine Society used preformed hemp wall panels to construct their warehouse at Stevenage in Hertfordshire in the UK. The warehouse demonstrated remarkable temperature stability. In use of energy the warehouse performed 65% better than their model has predicted and was 70% more efficient than existing warehouses[9].

The moisture buffering ability of hemp walls was the reason that The Science Group (a group consisting of several sizable museums in the UK) chose hemp/lime for the retrofit of its archive and storage facility. Heating and air conditioning is a big cost for galleries and museums who need to control temperature and humidity to preserve works and artefacts. The use of building materials rather than mechanical means to control temperature and humidity, results in energy and hence cost savings[10].

Hemp walls sequester carbon. As it grows the hemp plant takes carbon dioxide from the atmosphere and stores this carbon in its tissues. While the carbon dioxide remains in the plant material and does not break down it remains stored. Hemp grows much quicker than timber and stores carbon much faster. A square meter of 300 mm thick hemp wall will vary between locking up 107.5 kg of carbon dioxide or emitting 18.8 kg of carbon dioxide depending on the embodied energy of the binder and the re-carbonation of the lime. This compares to a standard cavity wall in the UK emitting 100-220 kg of carbon dioxide per square meter[11].

Hemp walls are fire resistant and some hemp binders available in Australia have been tested to 1 hour fire resistance, meeting the requirements of BAL FZ (Bushfire Flame Zone). When I was asked about the fire resistance of hemp I responded by doing a test on a block with a blow torch. The outer layer of hemp charred but it did not burn and did not spread the fire, the charred layer also did not penetrate into the test block. In a wall situation the hemp material covers the timber frame protecting it from fire[12]. Hemp walls are also non-toxic, pest and mould resistant and have good acoustic properties[13].

Hemp walls use one product to replace many layers used in conventional building – the plasterboard, insulation, building wrap and cladding (brick, timber or steel). The monolithic walls of the cast *in situ* method of hemp construction means that there are no air gaps in the walls and it is easier to seal the walls to other building materials. Air leaks in buildings are a big source of poor building performance in Australia.

How do you build with hemp?

The most common method of hemp building currently used in Australia is the cast in situ method. In this method a temporary formwork is attached to a loadbearing frame. The frame is most often timber but steel frames can also be used. The formwork is spaced out from the frame so that the hemp/lime mix will cover the frame on both sides. The hemp shiv is mixed with a lime based binder and water in a pan mixer (also called a mortar mixer). This mix is then placed in the formwork in approximately 150 mm layers and lightly tamped down. Layers of hemp mix are successively placed and tamped until the 600 mm high formwork is filled. Further formwork can then be added to continue the wall or the formwork can be removed and moved up the following day.

Hemp is also used in other methods of construction and can also be used in precast panels and blocks or mixed with clay rich subsoil to make a hemp light earth mix.

Who is building with hemp?
Hemp as a building material is still a new product on the Australian market and currently the clients taking up this product are prepared to be market leaders. Most people in the building and design industry have still not heard of hemp building or do not understand how it is used, or the benefits of building with hemp.

Many of the clients interested on building with hemp are searching for environmental or natural building products. Hemp was featured in the book "How the Rethink Building Materials" edited by Dick Clarke, which introduced the product to many building designers, architects as well owners looking to build. Clients are being advised of the benefits of hemp building from their building designers and architects who are aware of the many benefits of this building material, but most building designers and architects remain unfamiliar with hemp as a building material.

Many permaculture groups have led the way in learning about hemp building through presentations and visits to hemp houses. A number of ecovillages in Australia have chosen to build with hemp and these have provided a great demonstration of the use of hemp in multiple house projects. Several hemp homes have been open for Sustainable House Day over the past few years and this has allowed the public to see them first hand. In areas where one hemp home has been built clusters of hemp homes have developed, where a builder or designer is familiar with hemp and has promoted it, and people looking to build have had the opportunity to see and feel the benefits of a hemp home for themselves

The profile of hemp as a building material in the eyes of the general public was given a significant boost by the 42 home project carried out by Kevin McCloud at Swindon in the UK and the subsequent television program featuring the houses. Further media coverage will help to raise the awareness and profile of hemp building, this is helped by hemp buildings winning awards such as the recent win by Balanced Earth Building of the Master Builders Association award for Energy Efficient Housing for their "Possum Creek Hemp Residence"

Opportunities
The construction method for cast in situ hemp/lime walls utilises a standard timber frame, this means that with a few minor amendments such as diagonal strap bracing used instead of sheet bracing, no triple studs and the location and spacing of studs to make attachment of the formwork and filling of the walls easier, the frame construction method is familiar to all carpenters and builders and the frames can even be made off site.

Plumbing and electrical services can run through the hemp walls and are installed prior to the hemp. The walls are then cast around the pipework. Electrical services should be installed in conduit and electrical wall boxes can be placed in the wall to finish flush with the formwork, for ease of installation and so that no hemp mix enters the wall box. Plumbing services should be well tested prior to the placing of the hemp mix in the formwork. This is much easier compared to other natural building methods such as mudbrick or straw bale where pre installation of services is difficult or services need to be chased into the walls later.

The casting of the hemp walls is not heavy work and it is easy for people of all ages to build with hemp. At a build at Wentworth Falls in the Blue Mountains constructed by volunteers, a 70 year old woman worked on the walls for the four days of the build and did a beautiful job. As the hemp/lime mix is made in a pan mixer and then usually poured out into flexible buckets for filling the walls, the size of the bucket or the amount that it is filled can be adjusted for the available workforce. The mix is poured into the walls in 150 mm layers then lightly tamped down with a wooden block on a handle called a “tamper” or simply with a gloved hand. The tamping is not forceful like in rammed earth, but just enough to bring the binder coated hemp particles into contact with each other and interlock.

The making of the hemp walls can be easily learnt, under adequate supervision, enabling owner builders, workshop participants, and volunteers as well as professional crews to mix and cast hemp walls. As the hemp industry in Australia develops the opportunity to have an economic use for the shiv provides further value to the crop.

Obstacles

With all the benefits of building with hemp its use should be more widespread, however, a number of obstacles currently stand in the way of its further uptake.

Firstly, hemp building is a new and largely unknown building technique to most builders and tradespeople. While some builders and tradespeople are open to be educated and learn about new materials others want to stick to what they know and are familiar with. Builders who have not worked with hemp previously may be reluctant to provide a quote or estimate or may simply refuse to take in the job. I have been advised by some Building Designers of builders talking clients out of building with hemp.

A great solution, if builders did not want to install the hemp walls themselves, would be for the development of experienced specialist hemp contractors, like there is in the rammed earth industry. Building Designers and Architects have no issue including rammed earth walls in their designs, knowing that their builder will simply subcontract the construction of the rammed earth walls to specialist contractors. These specialist contractors know their work very well, can provide accurate square metre rates for their work, have all the equipment and labour available and come in at the right time in the building sequence and efficiently and competently construct the walls. It is hoped that in the future that there will be similar specialist contractors for hemp walls and that this will lead to an increase in hemp building.

The erection of temporary formwork, to cast the hemp walls in, is time consuming and there is room for innovation for greater efficiency. Most commonly form-ply, OSB (oriented strand board) or plywood is attached directly to the centrally placed frame using screws. The formwork is temporarily held out from the frame using some type of spacer, although such spacers are usually removed prior to the placement of the hemp.

The hemp walls are usually placed in rises of 600 mm, then the formwork moved up. To save the time of repeatedly moving the formwork some builders will completely form up one side of the wall to the top plate, then will only need to move the formwork up on one side. This only works if the walls are made relatively quickly as the formwork needs to be removed to help the walls dry.

There are numerous types of reusable formwork available from the concrete construction industry but these are often much stronger than what is required for hemp walls and correspondingly their cost is quite high. Plastic formwork that locks together with clips is easy to use and quick to move, but again the high cost of this can be a barrier to having enough of this type of formwork to build a whole house.

James Isaacs from Belubula Hemp Homes has been using a novel method to speed up his formwork. He has attached a number of sheets of 600 mm high form-ply together and strengthened them by attaching two steel rails. Such huge pieces of formwork would be cumbersome and heavy, but he raises them up using two mechanical hoists. It is this type of ingenuity that will help to deliver greater efficiencies in the hemp building industry.

Currently hemp shiv is being transported long distances or being imported from overseas for building as there is rarely a suitable supply locally available. Hemp shiv is lightweight but very bulky and transport over long distances can be very expensive and disproportionate to the cost of the material. The local availability of hemp shiv for building would be a great boost. To do this not only does hemp need to be grown in more places throughout Australia, it needs to be processed suitably for building close to where it is grown.

For hemp building there needs to be more consistency in the size of the hemp shiv. Ideally the shiv should be between 5 – 20 mm. Smaller hemp shiv will result in a wall with a higher compressive strength, but too small a shiv will reduce the air between the particles and reduce the insulation value. Too many small particles <3 mm reduce the porosity and adversely affect the drying process[14].

Future growth opportunities

The cast *in situ* method of hemp building has many benefits, such as creating seamless walls which assists in eliminating air leaks in the building envelope, however, it is time consuming and is a "wet trade" on site. Prefabricated panels can be made off site and therefore can make on site construction much quicker. Such panels can be SIPS which include the structural members as well as the hemp which provides the insulation as well as the inner and outer wall. Australian company, WA hemp building, is already producing a hemp cladding panel called "Rediclad". These panels are non-structural and are attached to the outside of the frame, like a much more sustainable version of the insulating polystyrene cladding. The hemp cladding panel are then finished with a lime based render.

To date hemp construction in Australia has been confined to the residential market. This is not the case in the UK where there have been a number of large high profile hemp builds such as the Marks and Spencer store at Cheshire Oaks, the Science Group warehouse and the Wine Society warehouse. One of the first large scale uses of hemp in a commercial build in the UK was the Adnams Brewery warehouse. This was a huge success for both the company and for hemp building. For Adnams Brewery it resulted in a building that kept a regular temperature and significantly reduced their energy costs. It also greatly increased the company's profile as being environmentally conscious. For hemp building it used innovative methods of construction and showed that hemp could be used in a commercial build with positive outcomes for the energy consumption of the building in use.

Another opportunity for the use of hemp shiv in construction is in block products. Again, such products can be produced off site, reducing the onsite labour component. Hemp block products can be either load bearing or non-loadbearing. A number of non-loadbearing hemp block products are available in Europe such as the French Chanvribloc, the British HCB Hempcrete blocks and the Dutch HempFlax ISO Hemp Block. Such non loadbearing blocks are usually built around a timber frame. Cannabric is a Spanish hemp block product which is load bearing and can therefore be used without timber or steel structural frame. Loadbearing hemp blocks generally contain a higher proportion of binder to increase their compressive strength but Canadian company Just BioFibre have overcome this by incorporating timber in their loadbearing blocks, creating blocks that look like hemp Lego. There is room in Australia for innovation in relation to the use of hemp in building products.

Hemp shiv can also be used to make chipboard-like compressed board products. The hemp shiv makes these products lighter than comparable wood based products and with the short growing cycle of hemp they are more sustainable.

Lower grade hemp fibre, not suitable for textiles, can be used to make bulk insulation batts. In the UK Black Mountain Insulation use the straw left over from hemp seed crops to manufacture bulk insulation batts for walls and ceilings.

The future of hemp building in Australia

Hemp is being used in beautiful, innovative, sustainable buildings across Australia. This is being recognised with a number of hemp buildings winning awards. Such awards do a lot to promote hemp building and legitimise it in the mind of the public, but also recognise the great builders and designers who are using and promoting this wonderful material.

In 2015 the Culburra Hemp House designed and built by Kirstie Wulf of Shelter Building Design won a National Building Designers Association Award.

In 2016 the Marrickville Hemp Extension designed by Tracy Graham of Connected Design and Built by Nick Sowden of Sowden Building Solutions won the Marrickville Council Sustainable Building Award.

In 2017 the Possum Creek House designed by Michael Leung and built by Balanced Earth Building won the Master Builders Association Award for Energy Efficient Housing.

Further Reading

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13. *The Hempcrete Book*, William Stanwix and Alex Sparrow, Green Books 2014 pp 97-99 and *Hemp Lime Construction*, Rachel Bevan and tom Woolley, BRE Press 2008 p75-76.
14. Personal communication Pete Walker, University of Bath; *Bio-Aggregate-based Building Materials – Applications to Hemp Concretes*, Sofiane Amziane and Laurent Arnaud (eds), Wiley (2013); “Effect of hemp shive sizes on mechanical properties of lightweight fibrous composites,” N Stevulova, L Kidalova, J Junak, J Cigasova, E Terpakova. *Procedia Engineering* 42 (2012) 496-500. Note that these experiments were carried with MgO based binder.

Hemp products into the future

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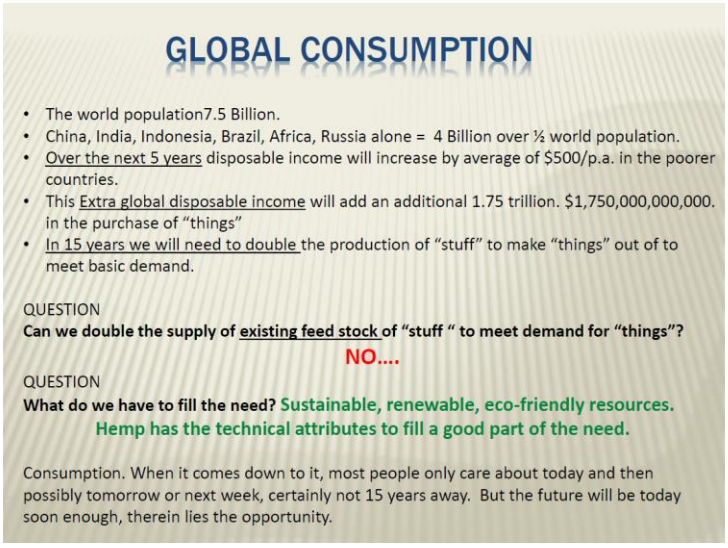


WHAT ARE WE DEALING WITH

MARIJUANA AND INDUSTRIAL HEMP = CANNABIS

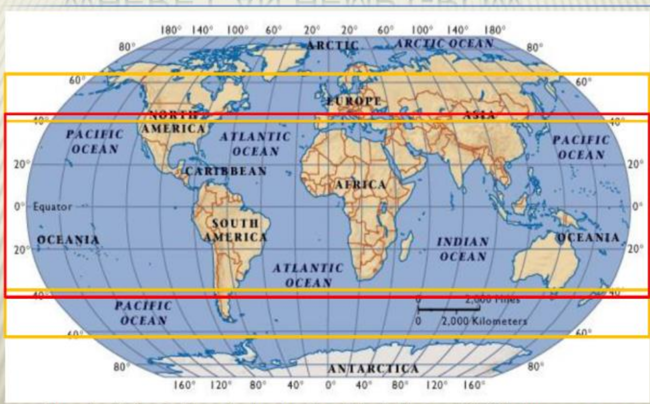
Did you know that there are over 2,000 different varieties of cannabis and that 90%+ of the cannabis species is non-drug

PLANT ANALYSIS

- Cannabinoids
- Seed Protein & oil profiles
- Mineral content
- Plant fractions
- Cell structures
- Compounds & performance
- And much more

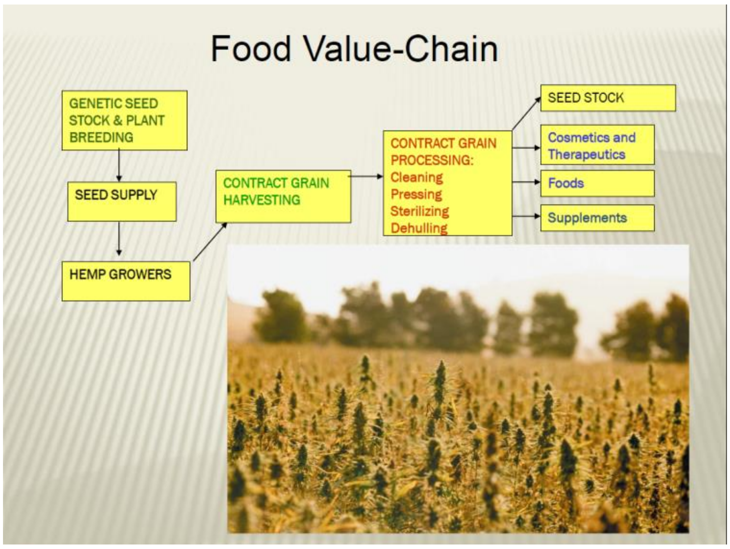
Nutrient		Units	Hemp Stalk Unretted
Nitrogen	N	%	0.57
Phosphorus	P	%	0.05
Potassium	K	%	0.41
Sulphur	S	%	0.13
Carbon	C	%	46.80
Calcium	Ca	%	0.577
Magnesium	Mg	%	0.230
Sodium	Na	%	0.038
Copper	Cu	ppm	5
Zinc	Zn	ppm	7
Manganese	Mn	ppm	159
Iron	Fe	ppm	45
Boron	B	ppm	12
Silica	Si	ppm	323
Molybdenum	Mo	ppm	<1
Nitrogen : Sulphur Ratio		units	4.5
Nitrogen : Phosphorus Ratio		units	11.4
Nitrogen : Potassium Ratio		units	1.4
Carbon : Nitrogen Ratio		units	82.7
Crude Protein		%	3.5

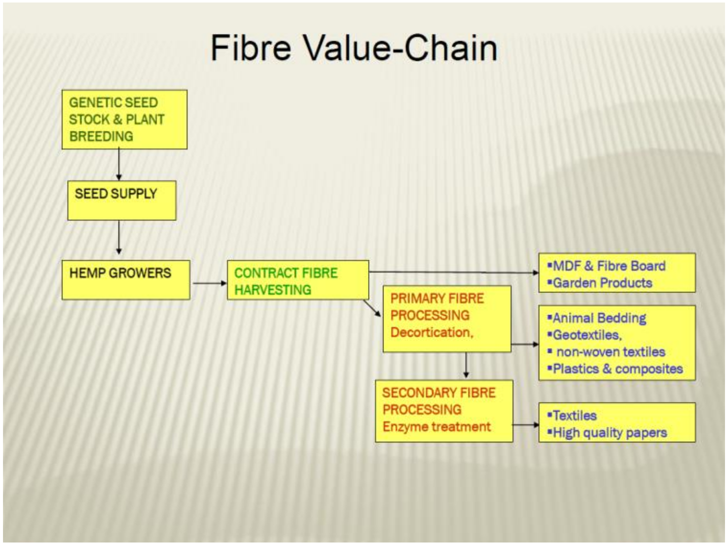
WHERE CAN HEMP GROW



Opportunity for Cultivars to be developed for latitudes 40°-0° to increase area of global production and higher yields.

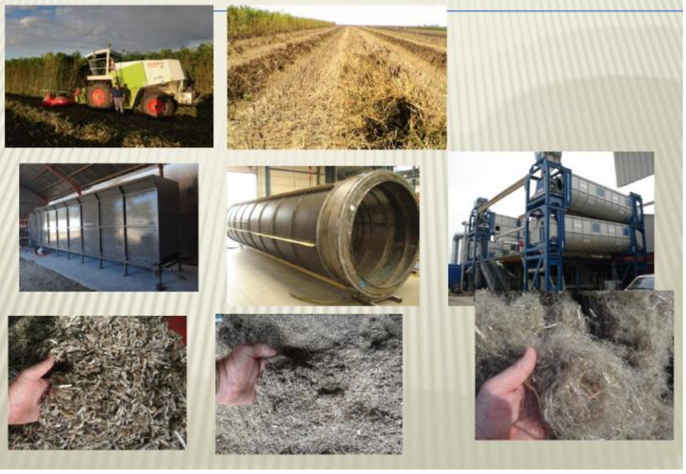

PLANT BREEDING
GENETIC SEED STOCK & PLANT BREEDING
• Specialized Pollen proof
• seed recovery chambers
• Auto nutrient & water
• 10 week period
• 80-100 Accessions per year


Food Value-Chain
GENETIC SEED STOCK & PLANT BREEDING
SEED SUPPLY
HEMP GROWERS
CONTRACT GRAIN HARVESTING
CONTRACT GRAIN PROCESSING: Cleaning Pressing Sterilizing Dehulling
SEED STOCK
Cosmetics and Therapeutics
Foods
Supplements


Fibre Value-Chain
GENETIC SEED STOCK & PLANT BREEDING
SEED SUPPLY
HEMP GROWERS
CONTRACT FIBRE HARVESTING
PRIMARY FIBRE PROCESSING Decortication,
SECONDARY FIBRE PROCESSING Enzyme treatment
•MDF & Fibre Board
•Garden Products
•Animal Bedding
•Geotextiles,
• non-woven textiles
•Plastics & composites
•Textiles
•High quality papers

Hemp Fibre

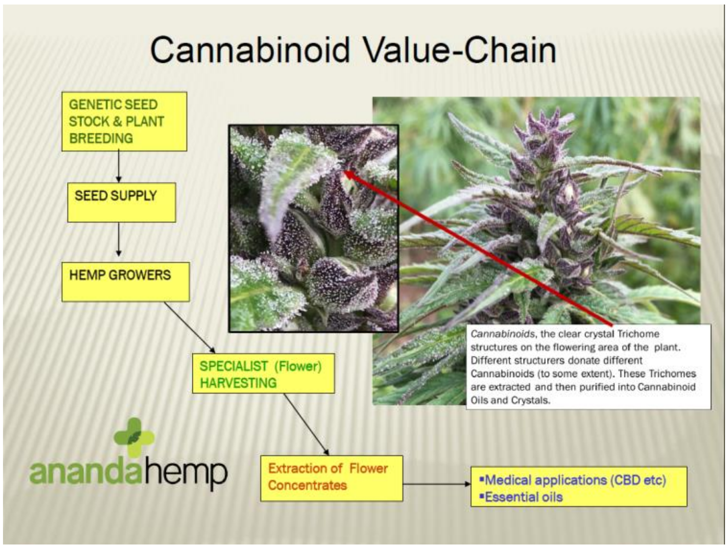
HARVEST, PROCESS, COMMODITY



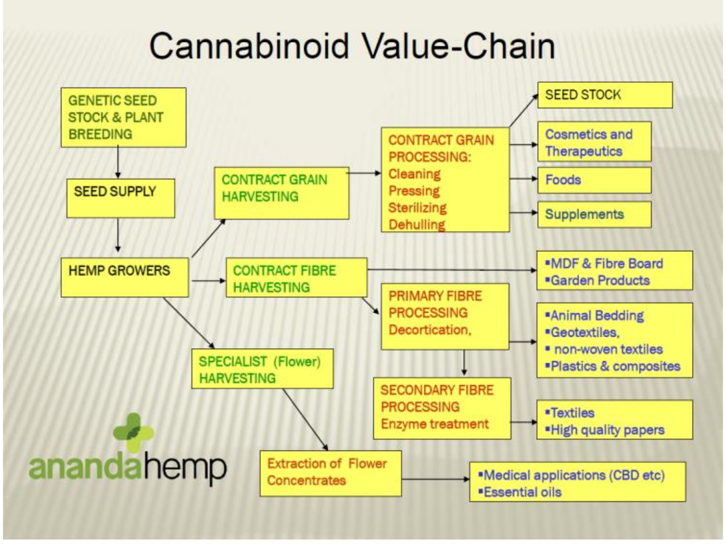
THE WORLD OF CARBON

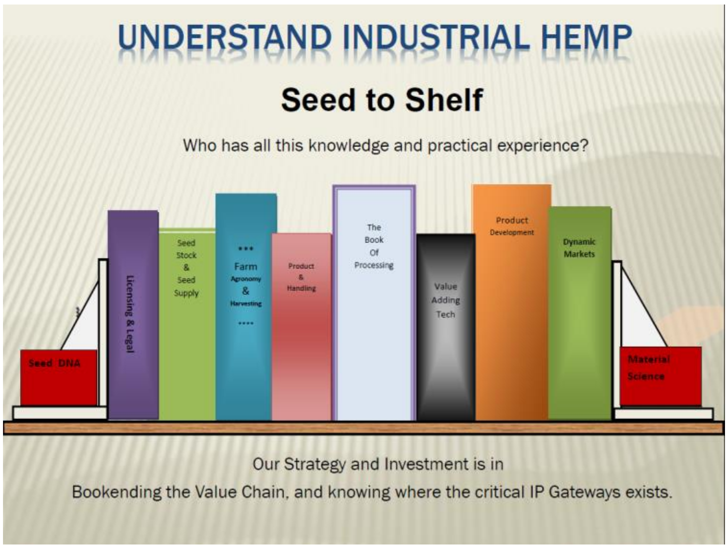
- Using the hurd carbon
- WHY IS THE HURD THE so important


OTHER HIGH TECH HURD APPLICATIONS
Hemp hurd powder can be used to:
· Make Silicon Carbide items such as ballistic products and bullet proof vests,
·Activated carbon, to be used for stack filters in all power generation, water filters, power storage.
·Ground powder for non-woven and fabrics as protective clothing for chemical and nuclear radiation
·As an antibacterial coating


Cannabinoid Value-Chain
GENETIC SEED STOCK & PLANT BREEDING
SEED SUPPLY
HEMP GROWERS
SPECIALIST (Flower) HARVESTING
Extraction of Flower Concentrates
▪Medical applications (CBD etc)
▪Essential oils
Cannabinoids, the clear crystal Trichome structures on the flowering area of the plant. Different structurers donate different Cannabinoids (to some extent). These Trichomes are extracted and then purified into Cannabinoid Oils and Crystals.
anandahemp


PHARMA-NUTRA-FOOD
• New categories created?
• What are we replacing?
• Who are we competing against?
• Consumer acceptance?
anandahemp





LOOKING AT HOW CAN A VISION COME TO REALITY

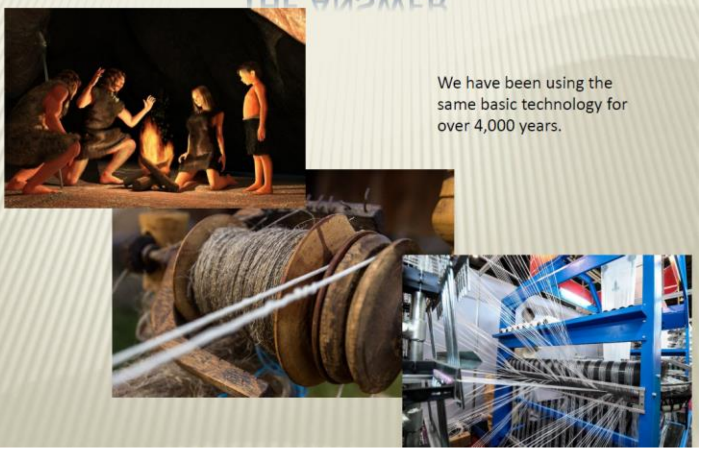
- Who are the competitors, how big are they? Can they be circumnavigated ?
- What are the hemp assets. Can you prove they are real?
- Hemp only, or hemp in combination with other synergistic resources.
- Is there an example of a previous new industry history to draw from?

FUTURE MANUFACTURING?

- Home manufacturing. An online industry, less transport, quicker turn around,
- Reduced need for centralised high density living/working,
- Less concentration of services, better and less use of energy.

INDUSTRIAL HEMP, THE ANSWER

We have been using the same basic technology for over 4,000 years.



MY VISION OF THE FUTURE HOW TO START & DEVELOPED

- Research the competitive and unique assets that hemp offers, work out the cost base.
- Design products for the future need, leap-frog over present technologies onto a level playing field.
- Predict when and the scale needed to deliver the product, be ready.
- Anticipate a hostile and competitive world that is the opposite to hemp in every way.
- Create a new currency, trading medium, standards, fluid & dependable exchange.
- Draw upon and learn from history. History has a habit of repeating itself when forgotten.
- Most of all, Collaborate, bring the people, your customers with you.

NOTES

AgriFutures Emerging Industries

Australian Industrial Hemp Conference 2018
Conference Proceedings

By Stuart Gordon
June 2018

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