TABLE 1: Dimensions and mechanical properties of single fibres

Fibre	Fineness (µm)	Length (mm)	Elongation (%)	Strength		Modulus	
				MPa	cN/tex	GPa	cN/tex
Hemp	3–51	8–55	2–4	690	47	70	2170
Cotton	12–17	20–32	6–8		32		500
Glass	4–20	3–15	0.5	2750	75	70	2940
Carbon	5–8	filament	1.4–1.8	4000		300+	

investigated. Improvements were measured as an increase in the number of productive soybean pods per plant and rate of photosynthesis.

It was suggested the responses were due to a reduction in the number of soybean cyst nematodes and/or a change in soil biochemical properties as a result of allelopathic chemical excreted by the hemp plant into the soil. It is noted more pertinent and rigorous assessment of these claims is required for Australian conditions. A much earlier study noted continuous cultivation of industrial hemp in monoculture might cause a rapid decrease in fibre (biomass) yield.

While it is widely suggested that industrial hemp can suppress weed growth, real evidence on hemp and weed competition is limited. Moreover, research in this area has occurred in the northern Hemisphere and as such, does not necessarily apply to the Australian situation. Pre-emergence weed treatment has been advocated by recent, larger growers in Australia to reduce the weed burden (contamination) in industrial hemp seed crops, which have more open stands than the European fibre crops from which conclusions about hemp's competitive nature with regards to weeds are often drawn.

Water and nutrition

In terms of water and nutrition, both cotton and hemp require reasonably significant inputs to achieve good yields. Australian cotton uses an average of 7.8 ML per hectare of water, from rainfall and irrigation, to achieve an average yield of 10.12 bales or 2297 kg/ha. There has been much less scrutiny of hemp's requirements.

Recent data from a large industrial hemp planting in NSW (in winter) and summer trial plantings in southern Australia showed water use ranged from two through to 11 ML per hectare, although like cotton this was dependent on a multitude of factors including region, soil type, water quality and crop type.

Viewing these numbers broadly on a season length basis, i.e., an average of 5.5 ML per hectare over 90 days for industrial hemp versus 7.8 ML per hectare over 180 days for cotton, shows the water requirement for industrial hemp, depending on the location and season, is probably very similar to cotton. The same scenario applies to N and other nutrient requirements.

Harvesting of industrial hemp for fibre occurs as soon as the last pollen is shed but before seed sets, which is normally about 70–90 days after planting. Harvesting for seed occurs four to six weeks later than fibre harvest, depending on conditions, when 60–70 per cent of the seed has ripened and the seed heads have dried to a point where the seed can be released without shattering. Most of Australia's current industrial hemp crop is grown for seed for human consumption. Smaller areas are grown for hurd, the inner pith of the stem, which is used in 'hempcrete' in domestic housing.

None of the Australian crop has been harvested for fibre yet, as the post-harvesting processes to extract and properly refine the fibre from the stem do not yet exist in Australia. A problem for the bulk of the Australian hemp straw is that it will be seed straw, which has a much smaller biomass per ha and is cut dried at seed harvest. The dryness affects the natural degumming process or retting that is used to liberate the fibres from their composite sheath around the stem.

Comparison of each crop's products and farm-gate returns

While cotton and industrial hemp are different plants, they do share commonalities in the products for which each crop is grown. Both plants produce fibre. Cotton produces both seed and stem (bast) fibres (although the cotton plant stem bast fibre is not exploited) and industrial hemp produces a bast fibre which can be used in traditional textiles, non-wovens particularly for industrial end-uses, and composites. Both plants also produce an oily seed that can be used for food for humans and animals.

The fibre properties of each crop are summarised in Table 1. The fineness and length values given for industrial hemp represent the dimensions of single elementary fibres – single bast fibre cells separated out from the aggregated fibre bundle or sheath. It is important to note that degumming and retting processes applied to hemp do not necessarily result in the complete separation of the aggregated bast 'fibre' into its single cell units. So hemp fibre bundles are typically longer (0.5 to 5 m in length) and coarser (up to 500 µm in diameter). These properties are key in understanding the final end-use for these fibres.

The narrow range of fineness and length dimensions of cotton, along with the fact that each fibre is covered in a hydrophobic wax layer that helps the fibre survive breakage during mechanical processing through to yarn, determine its suitability in traditional textiles. These ranges are much wider in hemp, with the finest, single cell fibres being too short for traditional textile processing. Hemp textile processing relies on careful preparation of the aggregated bundles so the appropriate fibre length and fineness for spinning and textile comfort are achieved.

As well, because hemp fibres are not lubricated like cotton, hemp fibre is either wet spun from longer length bundle fibres that are drafted into shorter, finer fibres during spinning, or shorter bundle lengths prepared from a degumming process are spun with lubricated carrier fibres such as cotton, polyester or viscose on the short-staple spinning system.

Notable is the relative stiffness or 'modulus' of industrial hemp, which makes it an excellent substitute for glass fibres in composite products, or as a fibre in industrial non-woven products such as insulation or weed matting.

Table 2 lists the nutritional properties of industrial hemp with comparative values for canola and cotton seed. The high levels of the essential fatty acid (FA) omega-3 (ω-3) in hemp in ratio to the polyunsaturated FA omega-6 (ω-6) set hemp seed oil apart in nutritional quality from most other oilseeds. Western diets are said to be deficient in omega-3 FAs and excessive in the amounts of omega-6 FAs compared with the diets on which humans evolved and their genetic patterns were established. A range of diseases are associated with high omega-6 polyunsaturated FA diets including cardiovascular disease, cancer and inflammatory and autoimmune diseases. As well as having an excellent ratio of omega-6 to omega-3 FA, hemp seed protein also contains 75–80 per cent salt-soluble globulins or edestin and 20–25 per cent of water-soluble albumin as the main storage proteins, with edestin also being rich in the amino acids essential for human health.

TABLE 2: Nutrition and yield profiles of hemp, canola and cotton seed

Seed	Oil t/ha	ω–6 to ω–3 ratio	Lipid %	Protein %	C'hydrate %
Hemp	0.3	0.1–1.1	25–30	8–16	4–18
Canola	1	2:1	42	35	15
Cotton	1	No ω3	20	22	22

The yield of products from industrial hemp remains in question. Table 3 lists average production values for cotton plus yields from the top 20 per cent of cotton producers against recent Australian yields for the equivalent product from hemp. The top seed yield from Canadian industrial hemp growers is provided for comparison. There is certainly much scope to improve Australian industrial hemp yields via shared variety testing and optimising agronomic and harvest practices.

Table 4 lists the current farm-gate prices for the products in Table 3. An important point to note is that the cotton fibre and seed returns can be considered for the same crop whereas returns for the industrial hemp seed crop are currently limited to the seed value only. No post-harvest processing of the seed straw occurs yet, despite there being three to five tonnes per hectare of biomass available. The seed crop also requires extra post-harvest care to realise these returns. The seed must be dried after harvest and stored under cool, dark conditions. The return on hurd also requires that on-farm decortication of the stem and packing of the hurd is available – akin to the ginning and cleaning processes for cotton. This infrastructure is currently limited in Australia.

TABLE 3: Australian yields (kg/ha) for cotton and industrial hemp farm-gate products 2017–18

Crop output	Average yield kg/ha 2017–18	Top 20% yield kg/ha 2017–18 (Highest Canadian yield)
Cotton fibre	2297	2865
Cotton seed*	5742	7163
Hemp fibre**	790–1220	
Hemp seed (grain)***	900–1280	3402
Hemp hurd****	1430–9090	

*Assuming 227 kg/bale and 40 per cent turn out at gin.
**Theoretical percent fibre from 15-25 per cent of the dried stem mass.
***Range from 2017–18 SA, NSW, TAS & VIC crops.
****Range from 2017–18 SA & NSW crops.

TABLE 4: Farm gate value in Australia ($/ha)

Crop output	Average return $/ha 2017–18	Top 20% return $/ha 2017–18
Cotton fibre	4959	6399
Cotton seed	1254	2506^
Hemp fibre?	?	?
Hemp seed (grain)^^	2588-3703	3703
Hemp hurd^^^	420-2700	>9000

^Drought price of $350/t
^^$2.50-3.50/kg
^^^$300–1000/t

To sum up

Much remains to be done in the Australian industrial hemp industry. The industry is fledgling. Varieties, regions and agronomic practices need to be determined and thought given to post-harvest processing and the logistics around transporting and consolidating the large but light-weight biomass.

Despite its long history, the industrial hemp industry is still very small (120,000 hectares of crop area around the world) and as such suffers from a lack of critical mass in research and technology development, which has characterised the development of other major crops. That said, its seed and biomass value will likely become more important into the future for the seed's excellent nutritional properties and for sustainable building and industrial textile materials.

Industrial hemp will not replace cotton's traditional place in the textile world but there could be distinct synergies in crop rotation or refugia plantings with cotton, and certainly in the development of industrial and domestic textile and material products.

GROWING THE AUSTRALIAN INDUSTRIAL HEMP INDUSTRY TO $50M IN THE NEXT FIVE YEARS

The 2nd Australian Industrial Hemp Conference will be held in Fremantle WA from February 25 to 28, 2020. The conference will host experts and present plans to grow this fledgling but exciting 'new' industry.

Researchers, growers and the industry are now looking at how to grow the potential of this crop to benefit more growers, create new local and export markets and unlock its considerable potential. Products from industrial hemp crops can range from food and nutraceutical products through to material products such as hempcrete from the stem's inner core, and durable fibre for textile and non-textile end-uses.

This conference follows the success of the inaugural conference in Geelong in 2018. The organising committee with members from the WA Industrial Hemp Association, the Australian Industrial Hemp Alliance, RMIT University, Deakin University and CSIRO have organised excellent speakers and worthwhile pre and post conference activities, including workshops and a visit to a WA industrial hemp farm.

Covering all aspects

The conference will cover all aspects of industrial hemp from managing the crop for production of food, nutraceutical, fibre and materials products through to the post-harvest processing technologies required to take these products to the market. The conference is essential for growers, processors, marketers and researchers.

- Each Session at the conference will be concluded with a chaired Q&A session to stimulate discussion, debate and very importantly, cooperation. Sessions will cover:
- Industrial hemp for nutraceutical products
- International roundup; what's happening elsewhere in the world?
- Seed supply for Australia
- Crop agronomy – managing and harvesting your crop
- Food and health products
- Fibre and material products
- Industry cooperation and investment opportunities

The conference is very fortunate to have Bruce Pascoe (Dark Emu) and Michael Robertson (CSIRO Agriculture and Food's Science Director) start with keynote speeches on the invention of agriculture and how past practices might, or indeed should be considered into the future. The talks by these eminent speakers will be instructive to all Australians interested in the agricultural potential of this crop and the production systems used in this country.

From this opening, the conference will move to another much-discussed industry topic. Could more temperate cannabinoids be a harvestable product for Australian industrial hemp growers? Speakers addressing this question will include Professor Tony Bacic from La Trobe University's ARC Medicinal Agriculture Hub, Professor John Skerritt from the Department of Health, Mike McGuire, Director Canadian Controlled Substances and Cannabis Branch, Paul Mavor from Health House and Medical Cannabis Research Australia and Dr Amie Hayley from the Centre for Human Psychopharmacology at Swinburne University of Technology. Industrial hemp is an emerging industry for its seed, hurd and fibre, but perhaps also for the nutraceutical market.

International updates

Representatives from around the world will provide updates on the industrial hemp crops in their countries. Production numbers, product focus, regulation and future projections will be presented by expert representatives from Europe, Canada, China and NZ. Phil Warner (Founding Director of Ecofibre International) will lead the introductions and discussion with these experts

The seed supply and crop agronomy sessions will hear from seed supply companies, crop consultants, researchers and growers on what seed, how to grow it and what's needed in terms of research and development. This session includes a live cross to a Tasmanian seed hemp harvest courtesy of Red Agriculture for a Q&A session in the field. AgriFutures Australia, the federal research and development corporation for developing emerging agricultural industries will also present plans for the industry and the development of national variety trials.

Products from the industrial hemp crop will also be presented and discussed. Innovations and tribulations will be shared on the opportunities from this crop. There is no doubt food (seed) and nutraceutical products from the crop will grow, but will the products from the fibre and material biomass be able to follow? Experts from industry, Australian universities, state departments of agriculture and CSIRO will report on the prospects and challenges around hemp's farm-gate products.

The final session of the conference will have speakers from government and industry talk on investment opportunities, carbon sequestration possibilities, changes to regulation and industry cooperation. Forms of growing raw material, of processing the raw material and its reusability in the sense of resource conservation will be looked at from these perspectives. Product transparency and traceability will also be addressed in this session.

The conference, which will be held at Fremantle's iconic Esplanade Hotel, will also host workshops, industry exhibitors and provide excellent opportunities for conversation and networking. The conference will culminate in a hemp-inspired dinner. Details can be found at *www.australianindustrialhempconference.com.au*

ASK AN EXPERT – HOW CAN I IMPLEMENT THE 'MIX AND ROTATE' STRATEGY TO COMBAT HERBICIDE RESISTANCE?

WEED smart
every weed every seed
every farm every year

With Tony Lockrey, Consulting Agronomist, AMPS Agribusiness, Moree

MIXING and rotating herbicide modes of action is a key strategy in the WeedSmart Big 6 – but it's a herbicide response to a herbicide problem. So, while it's critical, it must be implemented within a diverse weed management program.

Tony Lockrey, senior agronomist with AMPS Agribusiness at Moree has seen herbicide resistance get out of control on some farms while other growers have responded early and managed to maintain a broader spectrum of effective herbicides in their program.

"It has to start with herbicide resistance testing," he says. "And this has to include testing for susceptibility. Knowing what does work is very important as you've probably already got a fair idea about what doesn't."

Once all the effective actives are 'on the table' it's time to look at what crops can be grown to allow the use of the widest range of herbicide groups in the rotation, and where you might be able to find synergistic mixes that can further delay resistance and potentially allow the use of actives that are no longer effective on their own.

"When we sit down to plan out an integrated weed control program we want to make sure there is rotation and mixing going on in each phase – in the fallow, pre-sowing, in-crop and for desiccation, where required," says Tony. "When this is done in conjunction with a determination to stop seed set and remove survivors then it is possible to keep weed numbers low."

With an increasing number of proprietary herbicide mixes coming onto the market, and the broad spectrum of synergistic and antagonistic interactions between potential mixing partners, it pays to be well-informed and to seek advice.

If I already rotate modes of action why do I have to mix too?

Short answer: Rotation buys you time; mixing buys you shots. Mixing and rotating buys you time and shots.

Longer answer: Rotation of effective modes of action can significantly delay the onset of herbicide resistance and needs to be built into your crop rotation plan. Herbicides in Group A and Group B are particularly susceptible to multiple exposure resistance with as few as six exposures being enough to select for the resistant mutation.

By mixing MOA groups, either in the same tank mix or applied separately to the same population (like a double knock), those plants that survive one MOA are often killed by the second.

How does testing for susceptibility help when there's a weed blow-out?

Short answer: Knowing what will work against a resistant population helps drive down the seed bank and helps you regain control.

Longer answer: One real-world example is a paddock near Moree where Group A resistant wild oats were discovered in 1998 following a history of repeated use of Topik (Group A – fop), Verdict (Group A – fop) and, later, Axial (Group A –

AMPS Moree consulting agronomist Tony Lockrey has seen good results when herbicides are rotated and mixed in each phase – the fallow, pre-seeding, in-crop and desiccation.