A comparative analysis of cotton and hemp production in Australia

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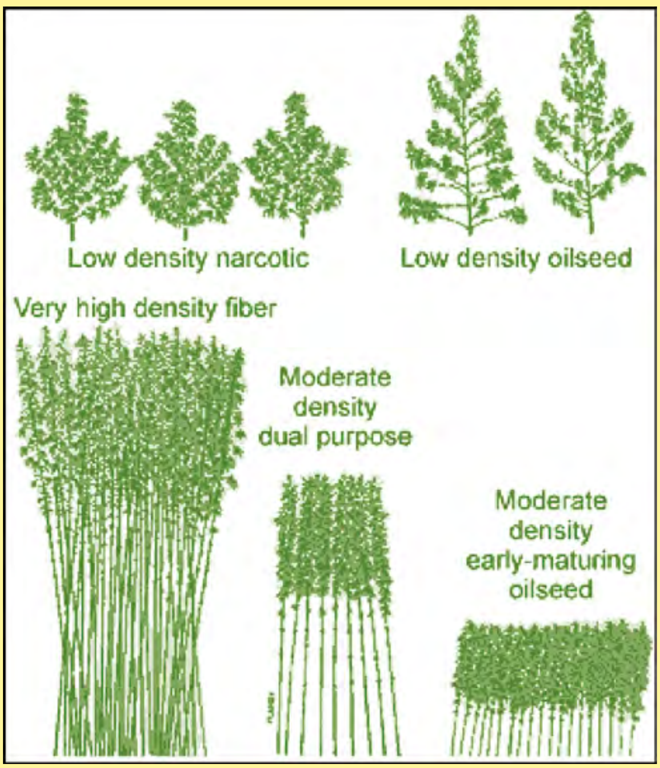
INDUSTRIAL hemp (*Cannabis sativa*) is an annual herbaceous, wind-pollinated flowering plant indigenous to eastern Asia but now of cosmopolitan distribution due to widespread cultivation. Like cotton, it has also been cultivated throughout recorded history with the earliest human uses of hemp going back 6000–10,000 years, during which time it has been used for manufacturing products such as, rope, paper and oil. But while industrial hemp has been cultivated for a long time, it has not been subjected to the same intensive agronomic and breeding research and development that has driven improvements in cotton and other major crops over the past 50 years.

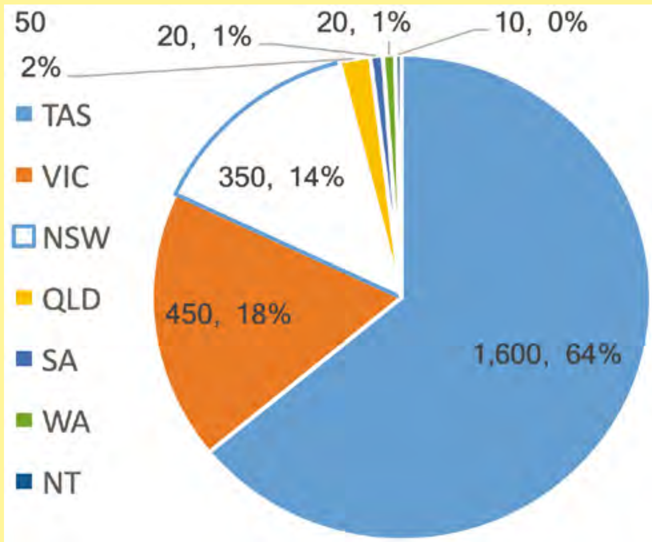
Industrial hemp and marijuana (medicinal hemp) are grown from the same plant species. The industrial hemp plant has lower values, stipulated by regulation, of the cannabinoid delta-9 tetrahydrocannabinol (THC), which is the principal psychoactive constituent of marijuana. Like most pharmacologically-active secondary metabolites of plants, THC is a lipid assumed to be involved in the plant's self-defence, putatively against insect predation, ultraviolet light and/or environmental stresses. Recent variety trials in southern Australia showed marked increases in THC in some varieties for late sown crops and when subsequent heat and water stresses are applied to the crop.

FIGURE 1: Typical architecture-types of cultivated *Cannabis sativa*



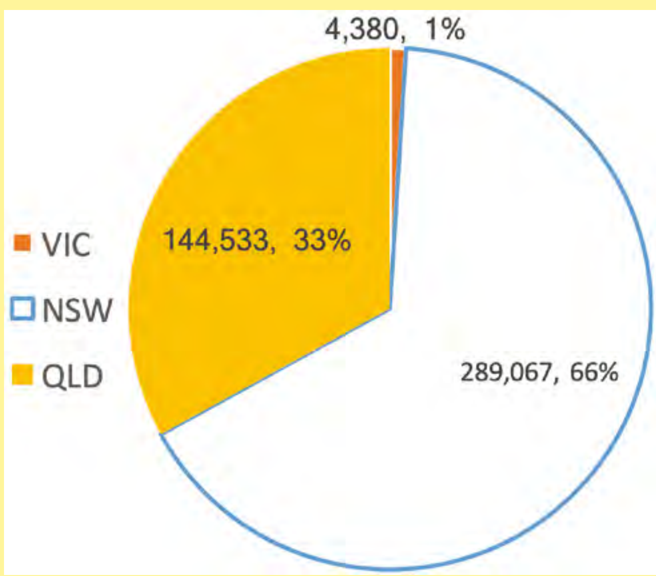
Top left: narcotic plants are generally low, highly branched and grown well-spaced. Top right: plants grown for oilseed were traditionally well-spaced allowing plants to develop to a medium height with strong branching. Bottom left: fibre cultivars are grown at high density and are unbranched and very tall. Bottom centre: 'dual purpose' plants are grown at moderate density, tend to be slightly branched and of medium to tall height. Bottom right: some recent oilseed cultivars are grown at moderate density and are short and relatively unbranched. Degree of branching and height is determined both by the density of the plants and their genetic background.

FIGURE 2a: Australian industrial hemp production by state area (hectares) and % location



Values from assorted sources – DPI in WA, SA, NT and VIC, UniTAS on TAS and CSIRO estimates for NSW & Queensland.

FIGURE 2b: Cotton production in Australia by area (hectares) and % location in 2018



Industrial hemp varieties exist in both diecious (separate male and female plants) and monoecious (hermaphrodite) forms. Plants have a shallower tap root (up to 0.5 metres) than cotton with more lateral fibrous roots and can grow to 1.5 to 5 metres in (stem) height. Height is variety dependent and crop architecture determines the end-purpose of the crop, e.g., for fibre, seed or both. Figure 1 illustrates the various architectural crop forms of the industrial (and medicinal) hemp plant.

Both crops are nominally summer crops, although industrial hemp can and has been grown in the warmer winter of the northern NSW and southern Queensland cotton growing areas. Industrial hemp growing regions extend further into the southern temperate cropping areas. Both crops require soil temperatures in excess of 15°C for optimum germination. And both can be grown on a range of soils with industrial hemp preferring shallower sowing depths (20 mm) on well-drained, light silty or clay loams. Industrial hemp is less tolerant to sodic soils than cotton. It is also intolerant of compacted soils particularly at seed germination. Once set, industrial hemp grows quickly, maturing in 70 to 90 days. Flowering occurs in many varieties at the summer solstice no matter the time of sowing. In contrast, cotton produces squares and flowers for about half its growing season, which extends up to 180 days before maturity.

The distinct photoperiod response of many industrial hemp varieties determines to a large extent the optimum regions (latitudes) for industrial hemp production, particularly for hemp seed crops. While there are adapted varieties for lower latitudes (and shorter day lengths), it is noted much of the large Chinese crop is grown north of the 39°N line, up to 47°N. And in Canada from 43°N up to 55°N. Similar location selection has occurred in Australia, with more than two-thirds of the current industrial hemp crop (for seed) being grown in Tasmania (40°S to 44°S).

Figures 2a and 2b show the Australian crop areas by state for industrial hemp and cotton in 2017–18. The industrial hemp crop area increasing significantly after November 2017, after state ministers responsible for food regulation considered Food Standards of Australia and New Zealand (FSANZ) approval of a proposal to permit the sale of low-THC hemp seed foods. Crop area jumped from less than 400 hectares before this ruling to more than 2500 hectares in 2017–18 (0.6 per cent of the cotton crop area).

Pests and diseases

Pests and diseases affecting Australian cotton crops are well documented and managed via pesticides, genetically modified traits and integrated pest management regimes. In contrast, there has been little investigation of pests and diseases affecting industrial hemp in Australia. Slugs, earth mites, cutworms, heliothis moths, Rutherglen bugs and birds have all been observed by local growers as indicative pests of industrial hemp. The small area and value of the crop to date means no chemicals are yet approved for use on industrial hemp.

Any current application must be covered by an Australian Pesticides and Veterinary Medicines Authority (APVMA) minor use permit. The Tasmanian Farmers and Graziers Association (TFGA) recently advocated to the APVMA that industrial hemp, because of its small crop area and its dual purposes (in terms of food), could fit in the crop permission groups of oilseed or cereal grains.

A recent survey of a winter crop in northern NSW identified industrial hemp as a possible host for a range of diseases affecting cotton. These included oxysporum, verticillium and sclerotinia, although evidence of crop damage or yield effects was not identified. Sclerotinia is a widely reported problem in Canada, affecting industrial hemp crops following alternate hosts including canola, sunflowers, edible beans and soybeans, and particularly after warm, moist conditions. One researcher stated it was advisable to avoid crops in the same rotation with industrial hemp varieties susceptible to pythium and sclerotinia. There has been no reported selection of industrial hemp varieties based on resistance to disease and/or pests.

A small number of studies have suggested industrial hemp could be a valuable break or disturbance crop. In the examples, industrial hemp provided a disease break for cereal crops and improved soil structure found industrial hemp had a positive effect for up to three years as a single disturbance crop in a continuous monoculture of soybean. The causal effect of the industrial hemp break crop on soybean yield was not

The primary products from industrial hemp: Top hemp fibre, centre hemp hurd and bottom hemp seed.

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.