Australian industrial hemp best management practice gap analysis

by the Industrial Hemp Best Management Practice Manual Working Group
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AgriFutures® Emerging Industries

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Foreword

Industrial hemp (*Cannabis sativa* L.) is an emerging industry that is gaining increasing attention in Australian agriculture. To help the industry grow, AgriFutures Australia invested in the development of an industrial hemp best management practice (BMP) manual and this associated gap analysis for growing, harvesting and processing hemp.

In putting together the BMP manual, gaps in information required by growers to sow, grow, harvest and initiate post-harvest processing of high-yielding and high-quality crops (for grain/seed and/or biomass) were identified. These gaps are the focus of this report, which will help prioritise future research, development and extension (RD&E) needs for the Australian industrial hemp industry. While this report is valuable now, different RD&E needs will develop as existing constraints are alleviated and new challenges arise.

This industrial hemp BMP gap analysis has been produced as part of AgriFutures Australia's Emerging Industries Program, which focuses on new and emerging industries with high growth potential. Emerging animal and plant industries play an important part in the Australian agricultural landscape. They contribute to the national economy and are key to meeting changing global food and fibre demands. Most of AgriFutures Australia's publications are available for viewing, free download or purchase online at www.agrifutures.com.au.

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AgriFutures Australia

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- Western Australian Department of Primary Industries and Regional Development (DPIRD)
- New South Wales Department of Primary Industry (DPI)
- Northern Territory Department of Industry, Tourism and Trade (DITT)
- Doyle Rural Services
- HempGenTech
- Growfield Agricultural Consultancy
- Australian Industrial Hemp Alliance (AIHA)
- Stoney Creek Oil

Abbreviations/definitions

AHC	Australian Hemp Council
AIHA	Australian Industrial Hemp Alliance
APSIM	Agricultural Production Systems Simulator
APVMA	Australian Pesticides and Veterinary Medicines Authority
Biomass	stem harvested for fibre and hurd refining; usually baled
BMP	best management practice
GM	gross margin
IHVT	Industrial Hemp Variety Trials
THC	tetrahydrocannabinol
WUE	water use efficiency

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Executive summary

This gap analysis provides an outline of areas requiring further focus by the industrial hemp industry and its research, development and extension agencies.

The Australian Hemp Council (AHC) and the Best Management Practice (BMP) Manual Working Group, with support from AgriFutures Australia, have established a BMP manual for growing and managing industrial hemp production and post-harvest practices in Australia. In putting together the manual, gaps in information required by growers to sow, grow, harvest and initiate post-harvest processing of high-yielding and high-quality crops (for grain/seed and/or biomass) were identified.

The BMP manual covers 10 key areas from farmgate products and services through to post-harvest processing. While these areas are generally well-understood in terms of the science and plant/material responses, there are many constraints to productivity that are not well-understood. These were identified during preparation of the BMP manual and are the focus of this document.

It is noted that research and development priorities will change over time as practices become accepted and new challenges, e.g., insect pests and new growing regions, arise.

The reader is urged to read this gap analysis after first reviewing the BMP manual.

Introduction

Australian industrial hemp industry

As agriculture in Australia continues to evolve, there is a need for producers to explore new and profitable opportunities. One opportunity gaining attention is the industrial hemp industry and the production of a range of hemp food and intermediate material products for Australian and overseas manufacturers and consumers. The Australian Hemp Council (AHC) and the Australian Industrial Hemp Alliance (AIHA), together with AgriFutures Australia, are committed to assisting this industry through targeted research and development investment.

The Australian industrial hemp industry has a goal a goal for domestic production of industrial hemp to have a gross value of production (GVP) of more than $10 million per annum by 2026. GVP is defined as the value of production realised at the point(s) of valuation where ownership of the commodity is relinquished by the farm enterprise or agricultural sector, such as harvested, refined, and/or graded produce sold into the wholesale market for processing and/or export. To achieve this benchmark, increased production is necessary. The ambition is for experienced growers seeking new opportunities to take up the crop for its grain, biomass and/or dual-cropping opportunities.

There was less than 2,500 ha of industrial hemp planted by more than 500 licence holders across Australia in the 2022-23 season.[1] Roughly half of this area was intended for grain/seed crops and half for biomass (hurd/fibre) crops (Figure 1). This is a reduction from the peak of just over 4,000 ha in 2019-20. The reduction is due to temporary overproduction of grain for food, floods in northern Victoria and western NSW, and a shortage of viable seed.

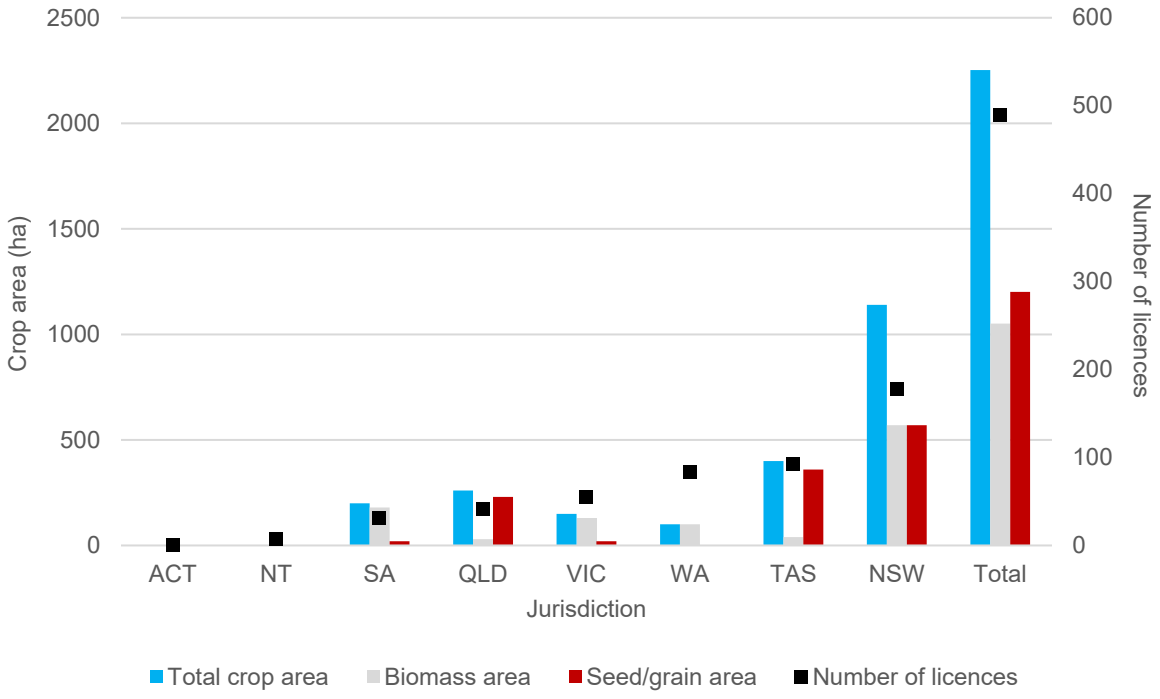

Figure 1. Industrial hemp crop area by type and number of licenses in 2022-23.

[1] Shane Herbertson, Chair, Australian Industrial Hemp Regulators Association, pers. comm., December 2022.

Industrial hemp BMP manual

The first edition of the *Best management practice manual for growing, harvesting and storing industrial hemp in Australia*[2] has been put together by a working group of growers, consulting agronomists, crop scientists and extension officers. The manual is aimed at new and existing growers, agronomists, and officers and researchers from state and federal departments of agriculture.

Members of the BMP Manual Working Group included:

- Stuart Gordon, CSIRO Agriculture and Food
- Mark Skewes, South Australian Research and Development Institute
- John Wightman, Natural Resource Development
- John Muir, hemp agronomist
- Rob Eccles, Eccles Agronomy and Agribusiness Services
- Don Telfer, WA Department of Primary Industries and Regional Development
- Induni Vijaya Kumar, NT Department of Industry, Tourism and Trade
- Karen Kirkby, NSW Department of Primary Industry
- Bob Doyle, Doyle Rural Services
- Omid Ansari, HempGenTech
- Angelo Rodrigues, Growfield Agricultural Consultancy
- James Vosper, Australian Industrial Hemp Alliance
- Tim Schmidt, Bernard Thomson and Jaimie Milling, Australian Hemp Council

The aim of the first edition of the BMP manual is to consolidate current information and extend this to current and new growers, so they can realise successful returns from the crop. This first edition also provides a template to update the manual so that outcomes from future R&D can be extended.

The current *Australian Industrial Hemp Strategic RD&E Plan*[3] identifies five key areas for research and development – regionally suitable varieties; better understanding of crop production; development of hemp products; an objective review of hemp's sustainability; and improved consistency of practice in state regulation. However, hemp crop areas are currently sporadic and small, which affects the quality of production information (seasonal nutrition, rotations, pest pressures and thresholds) and the resulting yield and quality. More information is required for industrial hemp to become a crop of choice for growers and the GVP benchmark set by the industry and AgriFutures Australia to be realised.

The information contained in the manual is largely verified by peer-reviewed research, most of it originating from overseas. But it also includes valuable unpublished, first-hand experiences from a coterie of expert domestic agronomists, breeders, growers and researchers, who kindly shared their experiences with the working group.

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[2] Gordon, S. *et al*. (2023). Best management practice manual for growing, harvesting and storing industrial hemp in Australia. https://agrifutures.com.au/product/best-management-practice-manual-for-growing-harvesting-and-storing-industrial-hemp-in-australia/

[3] Jefferies, S. (2022). *Australian Industrial Hemp Strategic RD&E Plan*. AgriFutures Australia, Wagga Wagga, NSW. https://agrifutures.com.au/product/australian-industrial-hemp-strategic-rde-plan/

Methodology

The BMP Manual Working Group examined the 10 key areas covered in the industrial hemp BMP manual, from farmgate products and services through to post-harvest processing. The information was reviewed and areas where there exist gaps were prioritised.

The review process was ongoing throughout the development of the manual and occurred during gazetted meetings for the manual, at Industrial Hemp Variety Trials (IHVT) program field days, and during AgriFutures Australia's Industrial Hemp R&D Workshop, held in Adelaide in January 2023. There were also many verbal and email conversations between members of the working group that contributed to manual development.

The areas reviewed for the gap analysis were:

- Farmgate products and services
- Varieties
- Climate and latitude
- Soil types and preparation
- Nutrient requirements
- Irrigation requirements
- Integrated pest, disease and weed management
- Rotation strategies
- Harvest and post-harvest practices
- Extension of information.

Table 1 summarises the key questions and nominated gaps arising from the working group's review.

In addition, a gross margin analysis was conducted to examine the relative profit from different industrial hemp production options. Information on receipts for baled stem, grain, fibre and hurd was drawn from first-hand experiences and/or contacts of the working group. Input costs were cross-checked against current gross margin models for broadacre cropping, including industrial hemp cropping and harvesting in Australia and Canada. The gross margin analysis highlights the role marketing and product extension need to play, particularly for farm biomass receipts.

Table 2 lists gross margins for grain, biomass and dual-purpose crops.

Table 3 provides a tabled action plan summarising the main **gaps** in each key area, with **action plans** and suggested entities/organisations with **responsibility** to address the gaps.

Discussion

Key focus areas and questions

Table 1 lists critical questions raised by the working group against key areas and sub-areas, and the priority attached to each with regards to the required industry focus and R&D investment. In total, 72 questions were raised across the 10 key areas. The listed questions reflect the broad consensus of the working group on key gaps in each area. Justifications for the questions were associated with crop yield, quality and returns to growers. The issue of regulation was also raised.

The working group deemed most questions (48/72) could only be answered by conducting research specific to industrial hemp crops and post-harvest practices. Industry practice models for other crops and/or products are not able to provide implicit or explicit information to improve industrial hemp crop yield or quality dividends in key areas.

However, the remaining (24) questions could be resolved, at least in part, by examining and/or adapting existing models for crop physiology and/or product handling, e.g., storage systems for fresh hemp grain. The application of crop (physiology) and integrated pest management models used for other crops also provides information on the effect of inputs (nutrient, water, pest management) and climate change on industrial hemp.

Prioritisation were considered chiefly from the perspective of individual farm businesses, where consideration is focused on yield and farm returns, rather than broader regional or industry-wide strategies. However, some priorities, e.g., Australian Pesticides and Veterinary Medicines Authority (APVMA) registration of pesticides for industrial hemp, need to be considered as part of a whole-of-industry strategy. At the same time, a priority like determining science-based action thresholds for when pest populations require control, first requires more comprehensive surveys of insect pests and beneficials, and crop damage.

To assess industrial hemp cropping in different locations and following scale-up of the crop area, and to then assess the crop's response to a future with climate change, the use of crop models, such as the Agricultural Production Systems Simulator (APSIM),[4] would be useful, particularly if they relate to the economic and ecological outcomes of management practices in the face of climate risk. These models are currently being used to explore options and solutions in the food security, climate change adaptation and mitigation, and carbon trading domains. The APSIM-type models developed for kenaf crops in northern Australia by Carberry *et al.*[5,6,7,8] serve as an example for industrial hemp.

In Table 1, 'First' priority areas address current and significant gaps in information. 'Second' priority areas are those where there is already applicable information or models for production and/or processing; investigation of these areas might be pursued once initial obstacles related to growing, harvesting and processing are overcome. 'Future' priority areas require the industry to have greater scale and available capital. The working group determined 41 of the 72 questions related to 'First' priority areas, 26 to 'Second' priority areas and five to 'Future' priority areas.

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[4] Agricultural Production Systems Simulator. (n.d.). *What is APSIM?* https://www.apsim.info/apsim-model/

[5] Carberry, P. S. *et al.* (1992). A simulation model of kenaf for assisting fibre industry planning in northern Australia: I. General introduction and phenological model. *Aust. J. Agric. Res.* 43, 1501-1513

[6] Carberry, P. S. and Muchow, R. C. (1992a). A simulation model of kenaf for assisting fibre industry planning in northern Australia, II. Leaf area development. *Aust. J. Agric. Res.* 43, 1515-1526.

[7] Carberry, P. S. and Muchow, R. C. (1992). A simulation model of kenaf for assisting fibre industry planning in northern Australia, III. Model description and validation. *Aust. J. Agric. Res.* 43, 1527-1545.

[8] Carberry, P. S., Muchow, R. C. and McCown, R. L., (1993). A simulation model of kenaf for assisting fibre industry planning in northern Australia. IV. Analysis of climatic risk. *Aust. J. Agric. Res.* 44, 713-730.

Table 1. Key questions for each key area and sub-area of industrial hemp production and post-harvest practice, and associated priorities.

No.	Area	Sub-area	Lead question	Critical question	Models to follow?	Justification	Priority 1	Priority 2	Future priority
1	Farmgate products and services	Farm returns	What products?	Regions and varieties?	IH specific	Little information	Y		
2		Grain/seed	For replant?	Storage conditions?	IH specific	Germination >85%	Y		
3				Storage pests?	Other products	Reported problem		Y	
4			Human food?	Ingredient value?	Other products	Product competition	Y		
5			Pet/animal food?	Benefits?	IH specific	New product		Y	
6		Biomass	Agronomics for fibre?	Process and grading?	IH specific	Product competition	Y		
7			Agronomics for hurd?	Process and grading?	IH specific	Product competition	Y		
8			Manufactured products?	Fibre applications?	Other products	Product competition		Y	
9				Composite product standard?	Other products	Product competition		Y	
10			Paper/pulp?	Product development?	Other pulp sources	New product			Y
11			Carbon benefits?	Account for built CO_2e?	IH specific	New service offer	Y		
12		Grazing hemp	Stock benefits?	Regulation?	IH specific	New opportunity	Y		
13				Weediness?	IH specific	Manage risk	Y		
14		Carbon farming	Carbon benefits?	Account for crop CO_2e?	IH specific	New service offer	Y		
15		Soil amelioration	Heavy metal uptake?	Crop disposal?	See research	New service offer			Y
16		Terpenoids	Products?	Use regulation?	IH specific	New product			Y
17		Cannabinoids	Yields?	Farm and use regulation?	IH specific	New product			Y
18	Varieties	Local germplasm	Breeding program?	Who, where and when?	IH specific	Yield and quality			Y
19		Traits	What traits?	Low THC?	IH specific	Regulation	Y		
20				Others?	IH specific	Yield and quality		Y	
21		Local varieties	Seed supply?	Who, where and when?	IH specific	Yield and quality	Y		
22		Imported varieties	Seed supply?	Certification?	IH specific	Yield and quality	Y		
23		All varieties	Time of sowing?	Location?	IH specific	Yield and quality	Y		
24				Inputs × location?	IH specific	Yield and quality	Y		
25	Climate/latitude	Variety	Location?	Periodicity response?	IH specific	Yield and quality	Y		
26				Degree day response?	IH specific	Yield and quality	Y		
27				Cold/hot shock response?	IH specific	Yield and quality	Y		
28			Harvest windows?	Seed head development?	IH specific	Yield and quality	Y		
29				Retting period?	IH specific	Yield and quality	Y		

No.	Area	Sub-area	Lead question	Critical question	Models to follow?	Justification	Priority 1	Priority 2	Future priority
30	Soil	Soil type	Soil types for hemp?	Survey – how/where?	Other crops	Yield		Y	
31		Soil preparation	Preparation for hemp?	Tilth and depth?	IH specific	Yield		Y	
32				No-till?	IH specific	Gross margin		Y	
33				Rotations?	Other crops	Gross margin		Y	
34	Nutrients	Soil type and pH	Crop requirements?	Emergence?	IH specific	Yield	Y		
35				Vegetative growth rate?	IH specific	Yield	Y		
36				Flower/fruit quality?	IH specific	Yield and quality	Y		
37				Effect of rotation?	Other crops	Yield		Y	
38		Nutrient source	Synthetic or bio?	Application rate?	Other crops	Yield		Y	
39	Irrigation	Application rates	Crop requirements?	Emergence?	IH specific	Yield		Y	
40				Vegetative growth rate?	IH specific	Yield	Y		
41				Flower/fruit quality?	IH specific	Yield and quality	Y		
42		Irrigation method	Cost?	Water use efficiency?	IH specific	Gross margin		Y	
43	Pests	Pest species	Effect on crop?	Where, what and when?	IH specific	Yield vs thresholds	Y		
44			What pesticides?	APVMA registrations?	IH specific	Yield	Y		
45				Role of beneficials?	Other crops	Gross-margin		Y	
46				Integrated management?	Other crops	Yield		Y	
47	Diseases	Disease type	Effect on crop?	Where, what and when?	IH specific	Yield	Y		
48				Soil microbiome health?	Other crops	Yield	Y		
49				Biosecurity practice?	Other crops	Yield		Y	
50				Resistant varieties?	IH specific	Yield		Y	
51	Weeds	Weed species	Effect on crop?	Where, what and when?	Other crops	Yield	Y		
52			What herbicides?	APVMA registrations?	IH specific	Yield	Y		
53				Reducing weediness?	Other crops	Yield and quality		Y	
54				Integrated management?	Other crops	Yield		Y	
55	Rotation strategies	Crop rotation	Crops in rotation?	Sequence and benefits?	IH specific	Yield	Y		
56				Soil carbon?	IH specific	Yield		Y	
57				Nutrient replacement?	Other crops	Gross-margin		Y	
58		Pests	Pest management?	Beneficials and trap crops?	Other crops	Yield		Y	
59				Resistance mitigation?	Other crops	Yield		Y	
60		Diseases	Disease management?	Disease mitigation?	Other crops	Yield		Y	
61		Weeds	Weed management?	Herbicide history?	Other crops	Gross-margin		Y	

No.	Area	Sub-area	Lead question	Critical question	Models to follow?	Justification	Priority 1	Priority 2	Future priority
62	Harvest and post-harvest practices	Grain	Harvest timing?	Seed head maturity?	IH specific	Yield and quality	Y		
63				Seed moisture/drying?	IH specific	Yield	Y		
64			Header settings	Manufacturer support?	Other crops	Yield	Y		
65			Crop weediness?	Grain cleanliness?	Other crops	Yield and quality		Y	
66		Biomass	Harvest timing?	Pre or post flower?	IH specific	Yield	Y		
67			Harvest settings?	Manufacturer support?	IH specific	Yield	Y		
68				Dual harvest systems?	IH specific	Yield	Y		
69			Swathing and windrow?	Periodicity and moisture?	IH specific	Yield and quality	Y		
70			Retting period?	Available moisture?	IH specific	Yield and quality	Y		
71			Baling?	Billet length and moisture?	IH specific	Yield and quality	Y		
72	Extension	Information	Delivery system?	Who and how funded?	IH specific	Yield and quality	Y		
				72 critical questions	**48 IH specific**		**41**	**26**	**5**

Note: IH = industrial hemp; Y = yes.

Figure 2 illustrates the number of critical questions raised in each key area. Areas with high-priority information gaps include farmgate products, varieties, integrated (pest/disease) management and harvest practice.

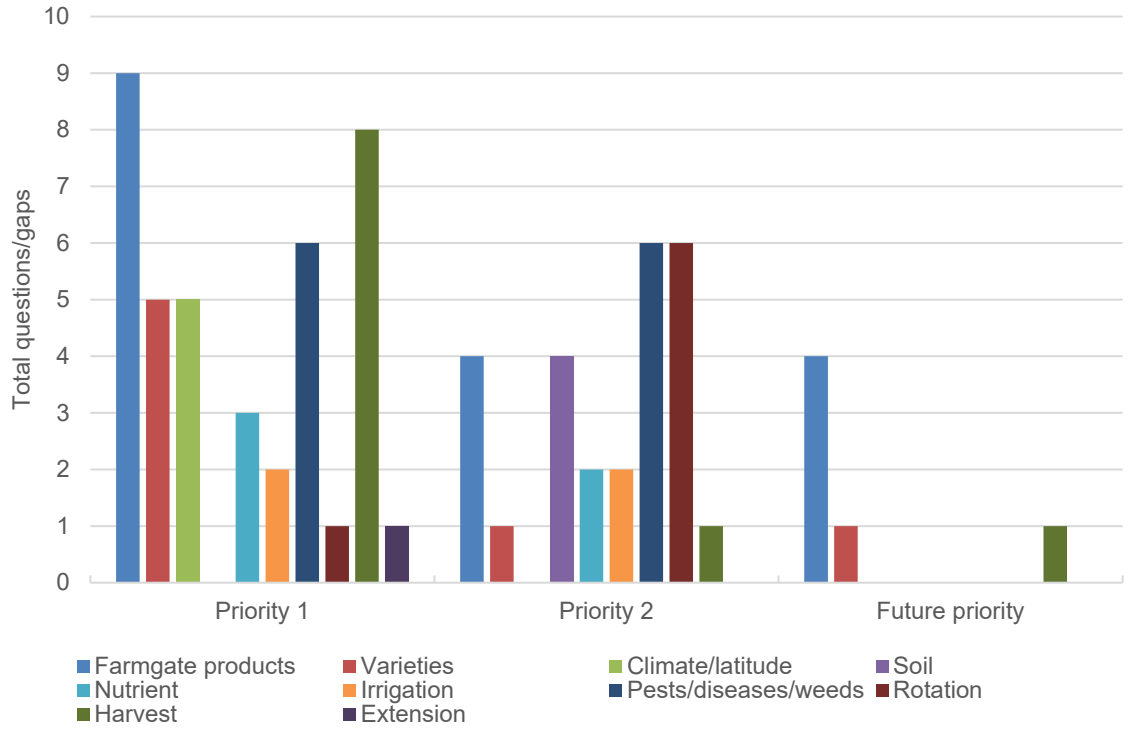

Figure 2. Number of questions/gaps raised in key areas described in the BMP manual for industrial hemp production and post-harvest processing – see also Table 1.

High priorities are attached to farmgate value discovery, particularly for biomass, and establishing go-to varieties and agronomic practices for high grain and biomass yields. Attention is also required to properly determine the carbon accounts for industrial hemp cropping. The 'service' of being able to provide a carbon offset will provide additional impetus for growers to consider the crop. There are no independent peer-reviewed papers examining carbon sequestration/offset accounting for Australian industrial hemp crops. Accounting for the sequestered carbon from the crop and its products after processing and distribution will be important in providing the industry with the foundations to build its credentials as a legitimate carbon offset crop.

High priorities are also attached to integrated pest and disease management of the crop. Gaps here relate to varietal selection (for disease resistance), pest thresholds, biosecurity measures related to disease transmission and APVMA registration of pesticides for industrial hemp cropping.

Second priority areas relate to soil, nutrition and water inputs and management for industrial hemp crops. These areas are common to other crops and, as such, there are already good models for industrial hemp to follow, although it is noted information specific to hemp cropping will be generated as the crop area grows and growers compete and seek to optimise inputs and crop outputs.

The development of new hemp products and standards, and the use of hemp as a forage crop for livestock are also listed as second priorities. These rankings reflect (i) the current small scale of the marketplace for industrial hemp products (and services); and (ii) that there are already mature processes to convert the crop's basic products, i.e., food grain, fibre and hurd, into higher-value products.

Greater importance (and priority) will be attached to standards describing the quality of industrial hemp's intermediates as the industry grows, and larger continuous supply contracts are required.

R&D investments in soil preparation and crop health, under different crop rotations, are deemed lower priority because these areas are largely understood and already being evaluated by growers and their agronomists. Examination of soil health and crop rotations will become more important with development of integrated crop management systems for soil diseases, weeds and insect pests. New management systems, including regenerative agriculture systems for industrial hemp, will arise as grower experience increases.

Future priority areas are nominated with the caveat their significance will depend on the foundations built upon reconciling current high-priority areas, and in the case of terpene and cannabinoid production, the introduction of regulation and systems that afford production of flower heads with non-psychoactive cannabinoids.

Breeding and trait selection are for the moment regarded as a future priority. It is assumed interest in these areas will follow once the industry achieves scale and consistency, and has impetus to further improve crop yields and quality. It is also assumed imported and adapted varieties will meet current production demands.

Gross margin analysis

Table 2 shows current average gross margins for an Australian industrial hemp grain, biomass and dual-harvest crops. The analysis assumes good soils, readily available water and crop inputs, and access to cultivation, harvest and cartage services or capability. Higher seeding rates are assumed for biomass crops. The water assumption is for irrigated water (3 ML/ha) on top of a local rainfall of ideally more than 500 mm/year. This means the analysis is applicable only to moderate-rainfall areas, and not low-rainfall areas, which will require irrigation. No costs for grain head desiccation have been applied.

Crop yields and price receipts for baled stem, and grain, fibre and hurd are deemed conservative. Higher prices and yields for grain and biomass have been received in the recent past.

Examination of costs and revenue reflects the high-priority areas identified in Table 1. Information (and investment) that support the crop's post-harvest management strategies, particularly those for the crop's biomass harvest, are highlighted. They include:

- Understanding the best varieties for region and farm yields.
- Determining the best harvest, retting and storage practices for biomass harvests.
- Promoting post-harvest machinery and processes required to realise saleable hurd and fibre streams from harvested straw.
- Determining standardised quality assurance tests for processed hurd and fibre to aid sale by description and promote initiation of longer-term supply contracts.

Realising consistent returns from biomass will be key for the industry to progress beyond its status as an interesting crop with good potential.

Associated with the above foci are priorities for seed certification to ensure good-quality growing seed is provided to growers, and variety trials that identify the best varietals by yield and quality, and by pest and water management requirements, for different growing regions. Ideally, varietal yield measurements and inputs will be determined for commercial-scale crops.

Table 2. Indicative income and variable cost items for industrial hemp crop production.

Product/service/input	Grain crop	Biomass crop	Dual crop
Income			
Hemp – straw (t/ha)	3	12	8
Hemp straw price ($/t)	200	400	300
Hemp straw return ($/ha)	**(600)****	**4800**	**2400**
Hemp – grain (t/ha)	1.3	0	0.8
Hemp grain price ($/t)	2500	0	2500
Hemp grain return ($/ha)	**3250**	**0**	**2000**
Seed drying and cleaning	-100		-100
THC and QA analysis/ha	-50	-50	-50
Total return ($/ha) – Scenario 1	**3100 (3700)****	**4750**	**4250**
Refined biomass returns***			
Hemp – hurd (@ $1500/t) @ 45%	2025	8100	5400
Hemp – fibre (@ $2000/t) @ 20%	1200	4800	3200
Hemp – trash (@ $400/t) @ 10%	120	480	320
Hemp – dust	?	?	?
Decortication (@ $600/t)	-1800	-7200	-4800
TOTAL return including grain ($/ha) – Scenario 2	**4645**	**6130**	**5970**
Variable costs			
Cultivation			
Primary (2 ha/hour @ $145/hour)	73	73	73
Secondary (4 ha/hour @ $135/hour)	34	34	34
Secondary (4 ha/hour @ $135/hour)	34	34	34
Seed			
Seed @$10.00/kg	320	500	400
Sowing (1.25 ha/hour @ $145/hour)	116	130	116
Fertiliser			
NPKS + trace (500 kg/ha @ $1250/t)	625	625	625
Fertiliser spread ($50/t)	25	25	25
Urea (100 kg/ha @ $1045/t)	105	105	105
Fertiliser spread ($50/t)	5	5	5
Other (seed dressing)			
Herbicide			
Herbicide (three types)	60	60	60
Spray boom (8 ha/hour @ $85/hour) x 3	35	35	35
Insecticide			
Insecticide (two types)	8	8	8
Crop spray (65 ha/hour @ $900/hour) ($/ha) x 2	30	30	30
Irrigation			
ML/ha @ $100/ML	3	4.5	3
Centre pivot pump @ $120/ML	360	360	360
Harvest			
Grain ($/ha)[9]	150	0	150
Biomass cut, swath and bale ($/ha)[10]	(450)**	1800	1400
Cartage and storage			
Grain pick-up and storage (@ $150/t)	180		120
Bale pick-up (to decorticator) (@ $30/t)	90	390	195
Agronomy services (100 ha min)			
Five four-hour visits during crop (@ $200/hour) ($/ha)	40	40	40
Total variable costs ($/ha)	**2500 (2950)****	**4704**	**4115**
Operating profit/loss – Scenario 1 ($/ha)	**600 (750)****	**46**	**135**
Operating profit/loss – Scenario 2 ($/ha)	**1605**	**1426**	**1855**

** Bracketed values for grain production include the addition of baled hemp grain straw sold at the farmgate. Underlined values add bale pick-up/transport costs to grain grower costs for decortication and refining.

***Using industrial hemp biomass fractions from Gordon and Miao (2023) – see Table 12; an average 45% of stem biomass will be hurd, 20% will be bast (fibre) and 10% will be plant trash (chaff). The remainder will be dust of unknown (?) or TBD value.

[9] Australian Custom Harvesters. (n.d.). *Costs Calculator.* https://customharvesters.org.au/cost-calculator/

[10] Australian Agricultural Contractors Association. (n.d.) *Contracting rates – fodder services.* http://media.heraldsun.com.au/weeklytimes/pdf/FODDER_rates.pdf. Note: 23.4% inflation added since 2013-14.

The price received in Scenario 2 (highlighted green) for returns on stem refined into hurd and fibre reflects the market structure for other agricultural commodities, e.g., cotton or wheat, whereby the grower pays for early-stage post-harvest processing (drying/cleaning/separation) and formal classification of the product, and then redeems the increased value of the product, which is now ready for manufacture.

Returns from hurd and fibre in this model will depend on the availability and proximity of efficient decortication and fibre refining facilities, ideally within 100 km of the production area.

Realising income from biomass is currently limited by the limited availability of post-harvest processing infrastructure, i.e., decortication, fibre refining and baling/bagging facilities. As per the analysis, this infrastructure is required so growers can access the excellent margins that could be available for biomass; in the realm of more than $1600/ha, and so grain growers can receive additional income from their seed crop straw.

The industrial hemp industry should investigate the processing, infrastructure and marketing model of cotton gins. Cotton gins separate the seed fibre from harvested seed cotton and provide growers with bales of fibre ready for marketing and sale into spinning mills. The average cotton gin in Australia (there are more than 40 across Australian cotton-growing areas) processes more than 100,000 bales of cotton per season, at 227 kg per bale. A cotton gin will run 24 hours a day, seven days a week for up to six months to provide growers with saleable product. The average cost of ginning on a per bale basis in 2021-22 was $85-95.[11] A bale (227 kg) of Australian base-grade cotton was selling for more than $600 in early 2023, or more than $2700/t. [12]

A cost of $600/t has been assumed for a high-throughput decortication and fibre-refining facility (assuming 2.5 t/hour). Cotton ginning costs in 2022-23 were about $400/t (or $90/bale). The $600/t estimate for hemp straw decortication and conversion is likely to be on the low side given throughput rates for single feed decortication systems are typically about 1 t/hour. This contrasts with an average cotton gin, which has feed rates of more than 8 t/hour of (raw) seed cotton to provide more than 3 t/hour of ginned, cleaned fibre.

[11] Shane McGregor, Australian Cotton Ginners Association, pers. comm., February 2023.
[12] Arthur Spellson, ADM Trading P/L Australia, pers. comm., March 2023.

Implications and recommendations

The working group survey of information (the industrial hemp BMP manual and Table 1) and a gross margin analysis (Table 2) have been used to review 10 key areas in industrial hemp crop production and processing. The review and analysis have highlighted gaps in information currently having a profound effect on development of industrial hemp as a crop and product.

Table 3 provides a summary of the priority **gaps** elucidated in each of the key areas, **action plans** (or recommendations) for each of the gaps, and the parties with **responsibility** for initiating the action plan(s) to close the gap(s). High-priority areas are highlighted in red.

It is important to note gaps highlighted in this report largely relate to realising good crop yields and quality. However, it is also evident there is an absence of market demand for farmgate products, especially biomass. To this point, efforts are required to increase awareness and demand for industrial hemp products. This could include marketing campaigns and educational initiatives to promote the benefits of hemp products and increase their visibility in the marketplace.

The relationship between R&D and marketing is synergistic. R&D can provide the foundation for new and innovative products and practices that can help growers meet the needs of the market, while marketing helps create demand for these products and connect growers with buyers. For example, if R&D identifies a new crop variety that is more resistant to pests and diseases, and produces higher yields, marketing can help to promote the benefits of this new crop to potential buyers, such as food processors or retailers. Alternatively, if marketing identifies a new market opportunity, such as growing demand for organic produce, R&D can enable development of new technologies and practices that can help growers meet this demand.

In terms of farm practice, there are clear gaps in information on the production, storage, and purchase of good-quality growing seed; the suitability and yields of varieties across regions; the agronomic inputs required to achieve profitable yields; and the realisation of good farmgate margins, especially for biomass crops.

While demand for industrial hemp products is increasing, the market in Australia is still relatively new and developing. Growers will benefit from access to market information and opportunities, as well as support to develop marketing and sales strategies.

Marketing recommendations are outside the scope of this analysis, however as per the recommendations on how to extend the industrial hemp BMP manual, the working group advocates the AHC and other industrial hemp industry associations formalise their structures, industry roles and formal/reporting relationships with each other. One of the association’s roles might be to promote Australian industrial hemp production and products.

Table 3. Industrial hemp crop and post-harvest practice gap analysis summary with action plans and responsibilities. Highlighted sections represent high-priority areas for R&D and extension.

Area	Assessment
Farmgate products and services	**Gaps – biomass:** Low gross margins for growers producing baled biomass. No standardised harvest or retting practices. Small and dispersed but growing capability in post-harvest processing of straw into hurd and bast intermediates. This capability can provide hurd for pet bedding, building and composite markets but has no ability to refine bast into a fibre acceptable for the higher-value non-woven and textile sectors. There are no established standards for describing the hurd or fibre intermediates. **Gaps – seed:** Market failure in consistent supply of certified, high-quality planting seed. Good-quality seed will have a high germination rate and genetic purity, and no contamination. This means the seed is produced from isolated crops of no more than two generations from the parent seed, has been cleaned of weed seeds, and has been stored under optimum conditions. Ideally, these practices will be declared on the seed analysis certificate.
	Gaps – grain: Information gaps exist relating to the techno-function properties of hemp grain flours and protein fractions in product applications; utilisation of hemp grain in beer malting and alcohol production; and methods to preserve the essential fatty acid content in fresh hemp seed oil for processed food and nutraceutical products. **Gaps – grazing:** The growth and health benefits from stock grazing on industrial hemp as a forage crop are not well-understood. Grazing windows on industrial hemp and crop rotations are not defined, nor has the issue of potential weediness been investigated. Standardised wait times for cannabinoid (THC) metabolism in stock need to be established, and the human-health effects of accumulated THC-COOH metabolite in animal fat need substantiating. **Gaps – carbon farming:** What does carbon capture in industrial hemp cropping and processing look like in Australian crop production systems? What are the average and distribution of values for soil and end-product carbon?
	Action plan – biomass: Formalise BMP procedures for biomass harvest and retting; initiate formation of an industry association for hemp biomass processors; promote grower payments based on the value of refined stem intermediate (hurd and fibre) rather than baled stem only. **Action plan – seed:** Advocate and extend seed certification to all industrial hemp seed suppliers.
	Action plan – grain: Explore processing techniques and the nutritional value of hemp grain flours and protein meals. **Action plan – grazing:** Establish the value of industrial hemp plant material as a forage feed; assess management strategies to prevent industrial hemp becoming a problem weed; initiate a research program to investigate wait times for, and the human health effects of, cannabinoid (THC) metabolism and metabolite accumulation in animal (cow and sheep) tissues. **Action plan – carbon farming:** Establish *bona fide* carbon accounts for broadacre industrial hemp cropping in Australia.

Area	Assessment
	Responsibility – biomass: AHC, AIHA and funding bodies such as AgriFutures Australia, plus an industry association formed by biomass processors, should liaise with growers and decortication and fibre processing machinery manufacturers to substantiate and guide BMPs for harvest and retting, and to promote intermediate (hurd and fibre) quality measures. *Exemplar is the Australian cotton industry.*
	Responsibility – seed: Industrial hemp seed suppliers and AHC to engage with the Australian Seed Authority. *Exemplars are seed suppliers into the Australian horticulture, grains and cotton industries.*
	Responsibility – grain: AHC, AIHA, funding bodies such as AgriFutures Australia and food processors to form relationships to further develop and market hemp grain as an alternate plant protein source, malting grain and/or fresh oil/essential fatty acid source. *Exemplars are the olive oil and flax seed industries.*
	Responsibility – grazing: AHC, funding bodies such as AgriFutures Australia and Meat & Livestock Australia (MLA), and Food Standards Australia and New Zealand (FSANZ), plus investigating universities and state departments of primary industries.
	Responsibility – carbon farming: AHC, AIHA and/or funding bodies such as AgriFutures Australia to commission an independent research agency or agencies to provide a peer-review analysis of industrial hemp's ability in Australia to be a *bona fide* carbon offset crop.
Varieties	**Gaps – varieties:** Current variety trials are small scale, and while they provide information on regional suitability for varieties and the best time to plant, they do not reflect broadacre yield potential or agronomic inputs.
	Gaps – low-THC varieties: Information gaps exist in understanding and managing the genetic and/or environmental prompts for THC production. Understanding these prompts will reduce the regulatory risk profile of the industrial hemp crop. Investigating this area also provides an opportunity to explore production of cannabidiol (CBD) and other cannabinoids.
	Gaps – seed supply and storage: See 'Farmgate products and services: Gaps – seed'.
	Action plan – varieties: Initiate variety trials on a larger scale (farm) so grain and biomass yield and quality can be determined in conditions that reflect commercial production.
	Action plan – low-THC varieties: Industry to initiate a collective survey of THC levels in IHVT program crops, other variety trial crops and commercial crops. The survey should continue for more than three years across regions and seasons. Collated information will provide insights into THC responses based on variety, location, crop inputs and seasonal stresses.
	Action plan – seed supply and storage: See 'Farmgate products and services: Action plan – seed'.
	Responsibility – varieties: Seed supply companies to supply seed to growers who agree to grow their crop using BMP-defined crop inputs, harvest practices and post-harvest processing. Yield results are compiled and publicised by seed suppliers, the AHC and the AIHA, and used to promote varieties and BMP inputs. *Exemplar is cotton seed distributors*.
	Responsibility – low-THC varieties: AHC, AIHA and funding bodies such as AgriFutures Australia to initiate a survey of THC levels. Breeders and researchers to initiate investigations to select (i.e., breed) (genetically) modified varieties and/or to manage crops for low THC.
	Responsibility – seed supply and storage: Seed suppliers to supply certified seed and/or adhere to an industry-recognised BMP practice. *Exemplars are seed suppliers into the Australian horticulture, grains and cotton industries.*

Area	Assessment
Climate/latitude	**Gaps – varieties:** See also 'Varieties: Gaps – varieties'. Information gaps exist relating to the periodicity response in varieties and the effects of day degree accumulation and cold/hot shocks. **Gaps – harvest windows:** See also 'Varieties: Gaps – varieties'. Information gaps exist relating to optimum grain and biomass harvest time, and biomass retting periods.
	Action plan – varieties: See also 'Varieties: Action plan – varieties'. Expand agronomic and climate information gathering at IHVT program sites and other variety trial sites. **Action plan – harvest windows:** Develop, test and extend procedures to assess seed head maturity, and biomass cut and retting dates. Procedures will ideally involve straight-forward subjective (identification) and/or quantification (measurement) tests. Procedures should be connected to measured yield and quality outputs. Additionally, explore the application of desiccants to grain crops to expedite harvest dates, and the application of moisture and/or fungal spore sprays to biomass crops to expedite retting.
	Responsibility – varieties: See 'Varieties: Responsibility – varieties'. **Responsibility – harvest windows:** AHC and funding bodies such as AgriFutures Australia to develop and extend consistent standards for determining grain and biomass harvest, and retting readiness dates.
Soil types and preparation	**Gaps – soil preparation:** Gaps exist relating to extension of practice to new growers of how to prepare soil and sow industrial hemp, including the use of no-till approaches. Additionally, information gaps exist relating to no-till preparation and the effects on soil health and crop productivity.
	Action plan – soil preparation: Conduct field trials comparing cultivated and no-till practices. Comparisons should be based on yield, soil carbon content, cropping efficacies and farm gross margin analyses.
	Responsibility – soil preparation: AHC, AIHA and funding bodies such as AgriFutures Australia to initiate field trials.
Crop nutrition	**Gaps – vegetative growth rate:** Information gaps exist relating to the nutrient requirements for improved vegetative growth rate and seed yield and quality.
	Action plan – vegetative growth rate: Conduct field trials to compare crop growth rate, yield and quality as a result of nutrient (N plus others) application and uptake. Trials should account for fertiliser form, rates, timing, soil condition and use efficiencies, including losses, particularly for N.
	Responsibility – vegetative growth rate: AHC, AIHA and funding bodies such as AgriFutures Australia to initiate field trials.
Irrigation	**Gaps – irrigation rate:** Information gaps exist relating to irrigation requirements (rates and volumes) for improved vegetative growth rate and seed yield and quality in different regions.
	Action plan – irrigation rate: Identify minimum plant available water content (in a range of industrial hemp soils) to achieve optimum vegetative growth rate and water use efficiency (WUE). Measure and extend information on the best water delivery mechanism (across a range of soils and slopes) to achieve optimum WUE.
	Responsibility – irrigation rate: AHC, AIHA and funding bodies such as AgriFutures Australia to initiate irrigation field trials.

Area	Assessment
Integrated pest, disease and weed management	**Gaps – pests:** Information gaps exist relating to understanding of pests, their extent and issues they create in industrial hemp crops. There are zero or few APVMA-registered pesticides for industrial hemp, and no defined management regimes or thresholds.
	Gaps – diseases: Information gaps exist relating to understanding of diseases, their extent and issues they create in industrial hemp crops. There is little or no information on industrial hemp varieties resistant to diseases, and no defined management regimes.
	Gaps – weeds: Information gaps exist relating to understanding of problem weeds, their extent and issues they create in industrial hemp crops. There are zero or few APVMA-registered weedicides for industrial hemp, and no defined management regimes.
	Action plan – pests: Conduct formal area-wide surveys of pests and their impact on industrial hemp crops. Surveys will provide information for development of management strategies and action thresholds. **Action plan – diseases:** Conduct formal area-wide surveys of diseases and their impact on industrial hemp crops. Surveys will provide information for development of management strategies.
	Action plan – weeds: Conduct formal area-wide surveys of weeds and their impact on industrial hemp crops. Surveys will provide information for development of management strategies.
	Responsibility – pests: AHC, AIHA and funding bodies such as AgriFutures Australia to initiate field surveys. **Responsibility – diseases:** AHC, AIHA and funding bodies such as AgriFutures Australia to initiate field surveys.
	Responsibility – weeds: AHC, AIHA and funding bodies such as AgriFutures Australia to initiate field surveys.
Rotation strategies	**Gaps – rotations for yield:** See also 'Varieties: Gaps – varieties'. Field trials do not currently incorporate rotations or measurement of their impact on varietal yield responses. **Gaps – rotations for disease (management):** See also 'Integrated pest, disease and weed management: Gaps – diseases'. Field trials do not currently incorporate assessment of disease impacts on back-to-back cropping of industrial hemp.
	Action plan – rotations for yield: See also 'Varieties: Action plan – varieties', with crop rotation scenarios and inputs. **Action plan – rotations for disease (management):** See also 'Varieties: Action plan – varieties' and 'Integrated pest, disease and weed management: Action plan – diseases', with crop rotation scenarios and inputs.
	Responsibility – rotations for yield: AHC, AIHA and funding bodies such as AgriFutures Australia to initiate field surveys. **Responsibility – rotations for disease (management):** AHC, AIHA and funding bodies such as AgriFutures Australia to initiate field surveys.

Area	Assessment
Harvest and post-harvest practices	**Gaps – seed harvest timing:** See 'Varieties: Gaps – varieties' and 'Climate/latitude: Gaps – harvest windows'. **Gaps – biomass harvest timing:** See 'Varieties: Gaps – varieties' and 'Climate/latitude: Gaps – harvest windows'. **Gaps – biomass harvest practice:** There is currently wide variation in harvest machinery used and practices for harvesting and billeting, swathing, tedding, and baling of industrial hemp crops. While practice depends on factors such as the intended end use, and climate and weather conditions, variations also mean inconsistent feed material is provided to stem processors, which compromises throughput and quality. **Gaps – retting practice:** See 'Climate/latitude: Gaps – harvest windows'.
	Action plan – seed harvest timing: See 'Climate/latitude: Action plan – harvest windows'. **Action plan – biomass harvest timing:** See 'Climate/latitude: Action plan – harvest windows'. **Action plan – biomass harvest practice:** AHC and AIHA to engage with harvest machinery manufacturers and suppliers. Collaborative field trials are proposed to assess the benefits of harvest and retting approaches to post-harvest processing. **Action plan – retting practice:** See 'Climate/latitude: Action plan – harvest windows'.
	Responsibility – seed harvest timing: AHC, AIHA and funding bodies such as AgriFutures Australia to initiate field trials. **Responsibility – biomass harvest timing:** AHC, AIHA and funding bodies such as AgriFutures Australia to initiate field trials. **Responsibility – biomass harvest practice:** AHC, AIHA and funding bodies such as AgriFutures Australia to initiate field trials. **Responsibility – retting practice:** AHC, AIHA and funding bodies such as AgriFutures Australia to initiate field trials.
Extension	**Gaps – who and how?** Most agricultural industries in Australia are represented by a range of formal incorporated member associations, e.g., representing consulting agronomists, grower valleys/regions and other service providers such as post-harvest processors. The questions for the industrial hemp industry, given the BMP manual will become a key resource for new and return growers, are which organisation should take responsibility for updating and publicising new editions of the BMP manual and how will this be funded?
	Action plan – who and how? The industrial hemp BMP manual can be used by industry associations, agronomists, and post-harvest processors to extend the practice of growing, harvesting and processing industrial hemp to new and return growers. The manual and this gap analysis also provide the industry with an R&D roadmap. Industry participants should discuss with funding bodies such as AgriFutures Australia how to manage and update future editions of the BMP manual.
	Responsibility – who and how? AHC, AIHA and other industrial hemp industry associations to formalise their reporting relationships with each other and nominate a lead association or representative working group to oversee production and publication of future editions of the BMP manual.

Conclusion

This analysis of industrial hemp farming and post-harvest practices was carried out via a comprehensive survey collated during development of the industrial hemp BMP manual. Working group members reviewed information across 10 key areas from farmgate products and services through to post-harvest processing. Seventy-two critical questions were raised and reviewed, and prioritised as 'first', 'second' or 'future' priority areas for R&D investment. Justification of the questions was clarified by gross margin analysis of three crop output scenarios for grain, biomass (for hurd and fibre) and dual-purpose (grain and biomass) crops.

The review and analysis identified considerable gaps in information relating to varietal performance in different cropping areas, agronomic practice and the transformation of industrial hemp stem into its intermediate products for sale and further manufacture. These areas, as well as harvest practices, were deemed be the biggest and most critical information gaps, and the main obstacles to the national crop achieving a GVP of $10 million per annum by 2026.

Recommendations relating to the 10 key areas are provided in detail below.

Farmgate products and services requires further information and development of post-harvest processing, storage (to preserve seed quality) and grading systems as a foundation of marketing and further developing industrial hemp products and farmgate viability. ***This is regarded as a high-priority area.***

Varieties requires further information on regional suitability, seed access and the influence of crop agronomy on yields. Ideally, variety field trials will be of greater scale and subject to current optimised production practices. Breeding and trait selection are regarded as 'future' and 'second' priority areas, respectively. The exception is selection of low-THC varieties and determination of low-THC environments and management regimes. ***This is regarded as a high-priority area.***

Climate and latitude is partially addressed in the current IHVT program objectives but the program should be widened to expand the planted area and enable commercial crop management testing in additional climates and at more latitudes.

Soils requires information about specific preparation for industrial hemp and sowing regimes to maintain soil health and structure.

Nutrients requires information about base nutrient requirements (for different soil types), particularly for plant development rates and crop type and yield.

Irrigation requires information about rates of irrigation for crop development and crop purpose (grain vs fibre/hurd), overall water use efficiency, and suitable irrigation systems.

Integrated pest/disease/weed management requires approved pesticides, biosecurity measures and a surveys to measure threshold actions and the role of beneficial insects. ***This is regarded as a high-priority area.***

Rotation strategies requires information on crop rotations and the yield, nutrient and IPM benefits.

Harvest and post-harvest practices requires information on harvested seed/grain crop storage and post-harvest retting and baling systems. ***This is regarded as a high-priority area.***

Extension of information requires industry participation on how the BMP manual can be published, updated and 'extended' for improved grower knowledge.

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by the Industrial Hemp Best Management Practice Working Group

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