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An analysis of the cultivation, consumption and composition of home-grown cannabis following decriminalisation in the Australian Capital Territory

Cilla Zhou[1,3,4,5], Isobel Lavender[1,2], Rebecca Gordon[1,3], Danielle McCartney[1,2], Richard C. Kevin[1,3,6,7], Miguel A. Bedoya-Pérez[1,2] & Iain S. McGregor[1,2]✉

The Australian Capital Territory (ACT), a region that includes Australia's capital, Canberra, decriminalised small-scale cannabis cultivation and possession in January 2020. Here, we examined cannabis use and cultivation behaviours, experiences and attitudes of current and past small-scale ACT cannabis cultivators. ACT residents (*n* = 311) who currently cultivate or have previously cultivated cannabis completed a cross-sectional online survey ('CAN-ACT') and provided home-grown cannabis for phytocannabinoid analysis (optional). Reasons for cultivation included a preference for home-grown cannabis to self-supply, enjoyment of the process and avoiding criminal networks. Cannabis intake was a median of 1 gram on a typical day used and the number of plants grown per year was a median of 4. Various cultivation challenges were identified, most commonly mould, nutrient deficiency and spider mites. Cannabis samples (*n* = 71) generally exhibited moderate THC content (mean 8.99 ± SEM 0.51% [w/w]) and low CBD content (< 0.1%). Few samples exceeded contaminant guidelines for heavy metals or pesticides. Respondents identified various grey areas in current legislation that might lead to inadvertent criminal activity, and many (52%) remained anxious about arrest. In general, recent legislative changes appear to support community needs. Options for further legislative refinement are discussed.

Keywords Cannabis, Cannabinoid, Cultivation, Contaminant, Drug policy

Recent significant shifts in global cannabis policies have ranged from the legalisation of cannabis in several countries (e.g., Uruguay, Canada) to more incremental reforms in others (e.g. Mexico, Brazil). Such incremental reforms include legalised access to medicinal cannabis products and decriminalisation of small cannabis possession for non-medical or adult use. Overall, there has been a noticeable shift away from policies wholly based on prohibition.

Australia has adopted cannabis policy reforms for medical use at both state and federal levels over the last decade. In 2016, the Australian Federal government introduced legislation allowing doctors to prescribe, and licensed companies to manufacture, pharmaceutical-grade medicinal cannabis products[1]. Since then, the number of prescribers, patients and products has increased dramatically, with medicinal cannabis now a common intervention for pain, anxiety, and insomnia[2,3]. Some barriers to patient access remain, such as the cost of prescription products and medical consultations[4,5], as well as driving restrictions[6].

[1]The Lambert Initiative for Cannabinoid Therapeutics, Brain and Mind Centre, The University of Sydney, Level 6, Building F, 94 Mallet St, Camperdown, Sydney, NSW 2050, Australia. [2]Faculty of Science, School of Psychology, The University of Sydney, Sydney, NSW 2006, Australia. [3]Faculty of Medicine and Health, School of Pharmacy, School of Medical Sciences, The University of Sydney, Sydney, NSW 2006, Australia. [4]The National Drug and Alcohol Research Centre (NDARC), University of New South Wales, 22-32 King St, Randwick, NSW 2031, Australia. [5]The National Centre for Clinical Research on Emerging Drugs (NCCRED), c/o University of New South Wales, 22-32 King St, Randwick, NSW 2031, Australia. [6]Department of Clinical Pharmacology and Toxicology, St Vincent's Hospital Sydney, Sydney, NSW 2010, Australia. [7]School of Clinical Medicine, Faculty of Medicine & Health, The University of New South Wales, Sydney, NSW 2031, Australia. ✉email: iain.mcgregor@sydney.edu.au

The use of non-prescription cannabis remains illegal in Australia at a federal level and those who use it continue to risk arrest and criminal conviction. However, significant legislative change around this issue occurred in January 2020 when the state government of the Australian Capital Territory (ACT) decriminalised small-scale cannabis possession and cultivation (Table 1). The ACT is a geographically small Australian region in which the nation's capital city, Canberra, is located. It has a socioeconomically advantaged and politically progressive population of approximately 450,000 residents, with around 30% employed within public administration, predominantly in Federal and Territory government bureaucracies[7]. The ACT government has historically implemented more liberal drug policy than other Australian regions[8,9].

Decriminalisation of home cannabis cultivation and use in the ACT follows similar relaxation in other countries such as Canada, Uruguay, Germany, Netherlands, Mexico and some states of the USA. The main intent was to reduce the burden on police and the judicial system imposed by trivial drug offences, and taking a public health approach[10]. Unsurprisingly, this legislative change has eliminated small-cannabis possession offences under the 'Simple Cannabis Offence Notices' scheme, and reduced overall cannabis-related arrests in the ACT[11]. Rates of cannabis use[12] and cannabis-related hospitalisations[13,14] appear unchanged.

Nevertheless, some ACT residents have raised concerns around apparent 'grey areas' in the legislation that may lead to unintentional illegal activity[15]. For example, it is unclear how cannabis seeds or plants can be legally acquired to initiate cultivation when it remains a criminal offence to possess, trade or sell cannabis under Australian Federal law[10]. It is also apparent that cultivating a legal number of plants (e.g. two) might readily yield illegal quantities of plant material (over the 50 gram limit) (Table 1).

From a public health perspective, there are no resources in Australia that provide advice or guidance on growing practices like there is for other plants. The quality of cannabis produced is unknown, particularly considering that cannabis is often smoked or vaporised[16,17]. Small-scale cannabis cultivators use chemical fertilisers, supplements and insecticides[18,19] and cannabis is an efficient bio-accumulator of heavy metals from soil[20]. Drying and storage could also lead to mould and bacterial growth[21]. Further, while the ACT government funded a free, fixed-site drug checking service in late 2021, they do not analyse cannabis samples for phytocannabinoid content[22].

The primary aim of the 'Cannabis Use and Cultivation in the Australian Capital Territory' (CAN-ACT) study was to investigate the cannabis use, cultivation practices, experiences and attitudes of small-scale ACT cannabis cultivators following the legislative changes of December 2020. Demographics, cannabis-use and cultivation experiences were compared to probe differences between current and past cultivators. The second aim was to analyse the contaminant and phytocannabinoid composition of the home-cultivated cannabis being produced.

Methods

Study design and setting

A cross-sectional study was conducted at the University of Sydney (Camperdown, NSW) between September 2022 and August 2023. It consisted of two anonymous components: (1) an online survey of participants' cannabis-use and cultivation behaviours and (2) an optional analysis of home-grown cannabis samples for cannabinoid and contaminant (heavy metals, pesticides, and mycotoxins) content. The investigation was approved by the University of Sydney Human Research Ethics Committee (HREC ID 2021/979). Authority was obtained from relevant authorities (ACT Health and NSW Health) for the Principal Investigator and delegates to acquire, possess, and supply cannabis plant material for the purpose of research.

Participants

Primary inclusion criteria included: (a) at least 18 years of age; (b) able to speak English; (c) a current ACT resident; and (d) experience cultivating or using cannabis. The primary methods for recruitment included social media (Twitter, Facebook, Reddit) advertisements, ACT television news features[23,24] and presentations about the study at an the ACT Hemp Expo and ACT "Cannabiz" Conference. All recruitment materials were targeted towards ACT residents who grew cannabis. Participants were not offered any remuneration or incentive other than the opportunity to have their home-cultivated cannabis chemically analysed.

Study procedures

Respondents accessed the CAN-ACT website (www.can-act.com.au) and read the Participant Information Statement before providing electronic informed consent and completing a short eligibility questionnaire. Eligible respondents were assigned a unique identification number ('CAN-ACT ID') and randomly generated password, that allowed them to initiate the survey, return to the survey at a later date, organise cannabis sample collection, and access the results of the chemical analysis once completed. The survey (Appendix 1) contained seven subsections (demographics, cannabis use behaviours, cultivation practices, medicinal use, non-medicinal use, adverse events, and attitudes towards legislation). Branching logic ensured that respondents only completed the sections that were relevant to their own use and/or cultivation. The survey took around 15–20 min to complete.

If you are aged 18 and over, you can now: • possess up to 50 g of dried cannabis or up to 150 g of fresh cannabis • grow up to two cannabis plants per person, with a maximum of four plants per household • use cannabis in your home (personal use)	It is an offence to: • smoke or use cannabis in a public place • expose a child or young person to cannabis smoke • store cannabis where children can reach it • grow cannabis using hydroponics or artificial cultivation • grow plants where they can be accessed by the public

Table 1. Summary of Australian Capital Territory (ACT) legislative changes (2020)[79].

Data were captured via a custom-designed database hosted on 'Wappsystem Pty Ltd' and securely stored on an Amazon Web Services server in encrypted form. Use of a proxy server ensured that participant IP addresses were not recorded.

Participants who reported current cannabis cultivation were invited to submit a sample of their home-grown cannabis for chemical analysis. Electronic consent to this process was obtained and then participants were given online instructions on how to package, label, and organise the collection of their sample with the study courier. A plant sample that corresponded to the cannabis that they typically consumed, weighing between 0.5 and 6.0 g, was requested. A total of 0.5 g was required for analysis of cannabinoid content, an additional 2.5 g for analysis of heavy metals and mycotoxins, and a further 3.0 g if the analysis was to include pesticides. Participants who chose to submit a second sample for analysis completed an additional cultivation sub-survey pertaining to the second plant submitted. The courier did not collect any identifying information from participants.

The cannabis samples were couriered to the Lambert Initiative laboratories at the University of Sydney (Camperdown, NSW), where they were weighed, photographed, logged and stored in a -20 °C locked freezer. If samples were of adequate size, a portion was then couriered to ChemCentre (Perth, WA) for contaminant analysis.

Chemical analysis

Phytocannabinoid analysis of plant material was conducted using a validated method[25] with minor adjustments. This used a Shimadzu (Kyoto, Japan) Nexera HPLC system with a Waters Aquity UPLC CSH C18 (1.7 µm, 2.1 × 100 mm) column coupled to a Shimadzu 8040 mass spectrometer, and Shimadzu Lab solutions software (v 5.89). Duplicate results from each sample were averaged, with cannabinoid concentrations represented as weight/weight (w/w) % ± standard error of the mean (SEM). When both the neutral and carboxylic acid conjugate were present for cannabinoid (e.g. Δ^9-tetrahydrocannabinol [THC] and Δ^9-tetrahydrocannabinolic acid [THCA]), the total content [e.g. THC_{total}]) was calculated according to standard methods[26,27].

Detection, identification and quantification of contaminants were performed as per Suraev, et al.[28]. The regulatory limits for mycotoxins, heavy metals and pesticides derived from the Australian Government Therapeutic Goods Order No.93 Standard for Medicinal Cannabis (TGO93)[29], which also aligns with the European Pharmacopoeia 10.0. 2.8.18 (European Pharmaceutical Standards for Medicinal Cannabis).

Data processing and statistical analysis

Preliminary data cleaning was conducted using IBM SPSS Statistics (Version 29.01.0) and further processing and statistical analyses using R v 4.3.1[30]. Descriptive exploration and data processing were done using the R packages "tidyverse"[31], "tidyr"[32], "dplyr"[33] and "Hmisc"[34]. The package "ggplot2"[35] was used to generate plots.

Data were first screened to remove ineligible respondents, those who had never cultivated cannabis and non-completions (Fig. 1). Only survey sections pertaining to demographics, cannabis-use, cultivation practices and attitudes towards legislation were included in this analysis.

Nonsensical responses were identified via the questions "*How many cannabis plants have you attempted to grow?*" and "*How many cannabis plants have you successfully harvested?*", where respondents indicated they had harvested from more plants than they had attempted to grow. These responses were only removed from data shown in Table 5 (see 'Limitations' section for further discussion). The relevant descriptive statistical analyses were then applied. Medians were chosen over means due to skewed distributions, which were assessed visually through histograms, and the interquartile range (IQR) reported. Missing data were omitted.

The statistical relationships between current and past cultivators and their cannabis-use behaviours and reasons for cultivating (categorical values) were analysed using Chi-squared tests of independence or Fisher's exact tests when cell sizes were small (expected frequencies < 5) for categorical variables. For continuous variables (i.e., age, age of first use, age of regular use and number of days of use in the last 28 days), Wilcoxon rank sum tests were used. All of these tests were conducted using the R base package "stats" and the functions *chisq.test*, *fisher.test*, and *wilcox.test*[30].

Linear regression was used to explore whether cultivation practices influenced THC content of cannabis. This employed the function *lm*, and *anova* from the package MASS[36]. Validity of assumptions was tested by Shapiro–Wilk test of normality, using the function *shapiro.test* from the package "stats"[30] and Levene's Test for Homogeneity of Variance (Homoscedasticity) using the function *leveneTest* from the package "car"[37]. Pairwise comparisons were performed using Dunn-Šidák corrections through the function *emmeans* from the package "emmeans"[38]. Statistical significance for all tests was set at $\alpha = p < 0.05$.

Results

Participants

A total of 516 respondents commenced the online survey (Fig. 1). Of these, 75 were ineligible to participate, 95 reported never having grown cannabis and 35 did not respond. This left a total of 311 eligible respondents for analysis. Future manuscripts will describe the characteristics of the wider sample, including the non-cultivators, while the present manuscript focuses on cultivators only.

Demographics and overall cannabis use behaviours

Respondents were asked "*Have you ever cultivated cannabis yourself?*". Those who selected "*Yes, I have previously or I am currently growing cannabis*" were defined as 'current cultivators' ($n = 253$; 81%) and those who selected "*Yes, but I no longer grow cannabis*" were defined as 'past cultivators' (n = 58; 19%). The demographics of these two groups are presented in Table 2.

The median age of respondents was 42 years old (IQR:32–54): most (69%) identified as male, 76% were tertiary educated and 69% currently employed. Most respondents resided in a house (80%), with a spouse/

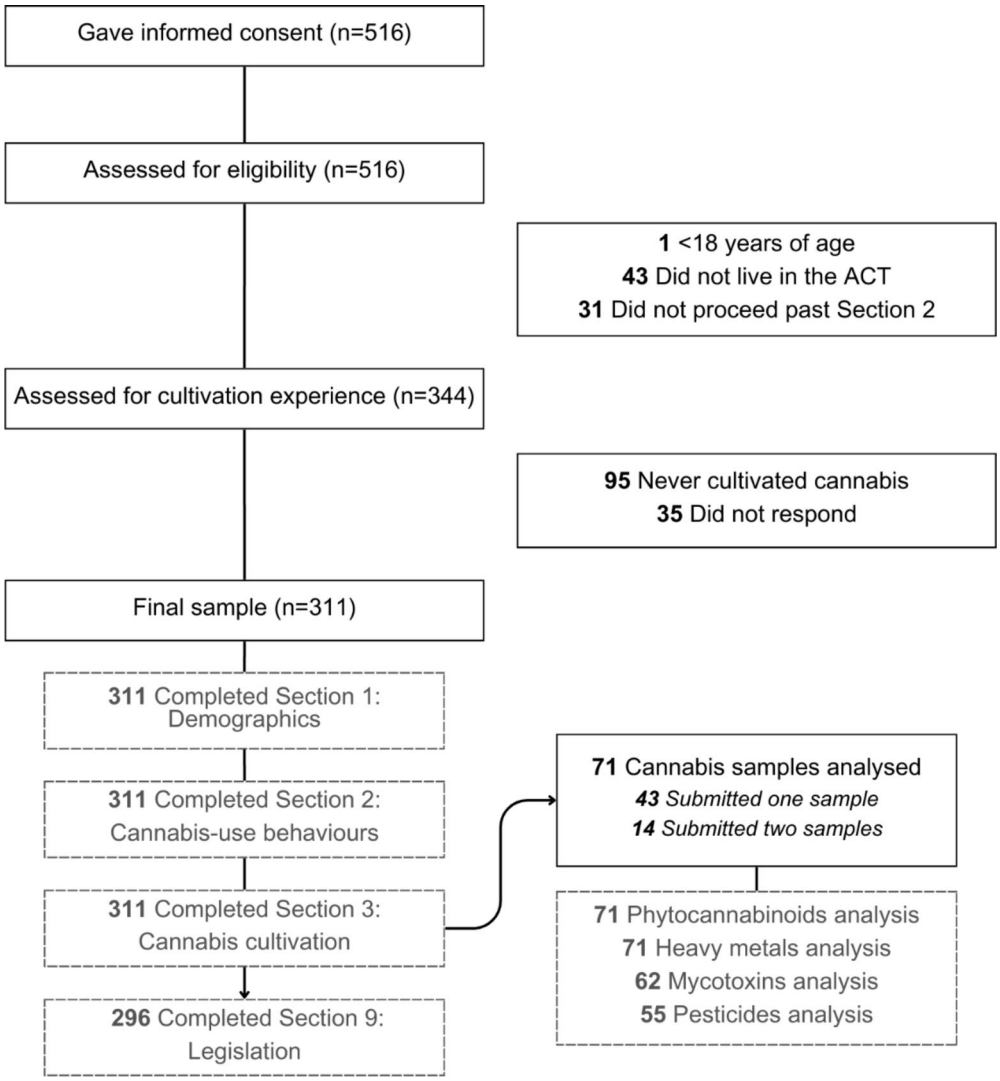

Fig. 1. Retention of respondents through recruitment, survey sections and phytocannabinoid and contaminant analysis.

partner (61%), friends/housemates (15%) and/or children (30%). Past cultivators were younger and more likely to live in an apartment with non-family members than current cultivators (Table 2).

Cannabis-use behaviours

Almost all cultivators had used cannabis in their lifetime (98%) and 91% were currently using cannabis. Their cannabis-use behaviours are reported in Table 3.

The median age of first cannabis use for these cultivators was 16 (IQR:14–18) and if they had ever used cannabis regularly, the median age they started regular use was 19 (IQR:17–25). Cultivators had used cannabis a median of 20 (IQR:3–28) days in the last 28 days. A large proportion (42%) of cultivators were using cannabis for dual medicinal (defined as cannabis used to relieve or treat symptoms of medical conditions) and non-medicinal (defined as cannabis that is not used to treat symptoms of medical conditions) reasons. Only 13% were using for medicinal-only, 36% for non-medicinal only and 9% stated they were not currently using cannabis.

There were no significant relationships between past versus current cannabis cultivators in cannabis-use behaviours (Table 3; $p > 0.05$ for all comparisons).

Cultivation behaviours and motivations

Cultivators were probed about their motivations for growing cannabis, how they sourced cannabis to grow, how much of their home-grown cannabis they consumed, and whether they shared it with others (Table 4).

Almost one-third (28%) of respondents reported initiating cultivation since the ACT legislative changes, and 15% reported growing for a year or less at the time of completing the survey (the survey was open almost three years post-legislation). One-quarter (25%) said that they started cultivating across the last 2–5 years (noting that this interval that overlaps with the legislative change in January 2020), and a total of 21% of cultivators had been growing for 6 + years.

	Current cultivators (*n* = 253)	Past cultivators (*n* = 58)	Total (*n* = 311)
Age median (IQR)	43 (34–55)	41.5 (28-48.75)	42 (32–54)*
Gender % (n)			
Male	70% (176)	66% (38)	69% (214)
Female	26% (66)	31% (18)	27% (84)
Other[a]	4% (11)	4% (2)	4% (13)
Tertiary educated[b] % (n)	78% (197)	69% (40)	76% (237)
Employment % (n)	69% (174)	69% (40)	69% (214)
Property type % (n)			
Apartment	12% (31)	33% (19)	16% (50)**
House	84% (213)	62% (36)	80% (249)**
Large property or farm	1% (2)	2% (1)	1% (3)
Granny flat	2% (4)	0	1% (4)
Other[c]	1% (3)	3% (2)	2% (5)
I live with[d]: % (n)			
Friends/housemates	12% (30)	26% (15)	15% (45)*
Spouse/partner	64% (162)	50% (29)	61% (191)
Children	30% (76)	31% (18)	30% (94)
Parents	6% (14)	5% (3)	6% (17)
Other family members[e]	4% (10)	4% (2)	3% (10)
No one, I live alone	16% (40)	14% (8)	16% (50)
Other	1% (3)	4% (2)	2% (5)

Table 2. General demographics. Asterix indicate Wilcoxon rank sum test with continuity correction, Chi-squared or Fisher's exact tests of independence between current and past cultivators: * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$. Some percentages may not total 100% due to rounding. IQR = interquartile range. [a]Includes 'other' and 'prefer not to say'. [b]Includes trade/vocational and undergraduate/postgraduate university qualifications. [c]Includes 'caravan or other mobile/temporary structure' and 'other'. [d]Percentages will not add up to 100% as question was multiple response. [e]Includes 'siblings or other family members' and 'grandparents'.

	Current cultivators (*n* = 253)	Past cultivators (*n* = 58)	Total (*n* = 311)
Lifetime cannabis use % (n)	98% (248)	98% (57)	98% (305)
Age of first cannabis use median (IQR)	16 (14.75-19)	15 (14–17)	16 (14–18)*
Age commenced regular cannabis use[a] median (IQR)	19 (17–26)	18 (17–24)	19 (17–25)
Days used cannabis in the last 28 days[b] median (IQR)	20 (3–28)	20 (3–28)	20 (3–28)
Reason for using cannabis % (n)			
Medicinal only	12% (31)	17% (10)	13% (41)
Non-medicinal only	34% (86)	43% (25)	36% (111)
Dual use	44% (109)	35% (20)	42% (129)
Not currently using	10% (24)	5% (3)	9% (27)

Table 3. Cannabis-use behaviours. Asterix indicate Wilcoxon rank sum test with continuity correction: * = $p < 0.05$. [a]Excluded those who entered '0' (indicates they have never used cannabis regularly; $n = 24$) and missing values ($n = 6$). [b]Excluded missing values ($n = 33$).

Primary motivations for cultivation included supplying self for non-medicinal (70%) and medicinal (61%) purposes and enjoying the process of growing cannabis (65%). Around half (48%) of the cultivators stated they grew cannabis to avoid contact with illegal suppliers, while 37% stated it was less risky than buying cannabis. A third (33%) of cultivators reported growing simply because it had become legal. Only 5% of cultivators grew to sell their product. Cultivators reported consuming a median of one gram (IQR: 0.2-2) of their home-cultivated cannabis on a typical day when cannabis was used.

Past cultivators differed from current cultivators on several comparisons: they were younger, more likely to reside in an apartment than a house and with friends or housemates. They also reported first using cannabis at a younger age. Current cultivators were more likely to report growing cannabis for the enjoyment of the growing process, to avoid contact with illegal suppliers and because it was a more consistent product or easier to buy. A higher proportion of current cultivators also grew cannabis to provide medicinal cannabis to others. They

	Current cultivators (*n* = 253)	Past cultivators (*n* = 58)	Total (*n* = 308)
Years spent cultivating cannabis % (n)			
< 1 year	16% (41)	7% (4)	15% (45)
Since the legislative change Jan 2020	30% (76)	21% (12)	28% (88)
2–5 years	29% (72)	12% (7)	25% (79)
6–10 years	7% (18)	2% (1)	6% (19)
10 + years	18% (46)	4% (2)	15% (48)
Reason for growing[a] % (n)			
To provide myself with cannabis for non-medicinal reasons	70% (178)	71% (41)	70% (219)
I enjoy the process of growing cannabis	72% (181)	38% (22)	65% (203)***
To provide myself with cannabis for medicinal reasons	62% (157)	55% (32)	61% (189)
To avoid contact with illegal suppliers	52% (132)	31% (18)	48% (150)**
The cannabis I grow is healthier than cannabis I can buy (e.g. free from heavy metals, fungi, or pesticides)	44% (111))	31% (18)	41% (129)
Growing cannabis is less risky than buying it	38% (96)	33% (19)	37% (115)
Simply because it has been legalised in the ACT	35% (88)	28% (16)	33% (104)
It is easier to grow than buy cannabis	30% (77)	12% (7)	27% (84)**
The cannabis I can grow is more consistent product than the cannabis I can buy	29% (75)	16% (9)	27% (84)*
I can share it/give it to my friends and acquaintances	31% (79)	7% (4)	27% (83)***
To provide others with cannabis for medical reasons	25% (64)	10% (6)	23% (70)*
For political or activist reasons	15% (39)	12% (7)	15% (46)
The cannabis I grow is stronger than the cannabis I can buy	15% (38)	10% (6)	14% (44)
The cannabis I grow is milder than the cannabis I can buy	11% (28)	5% (3)	10% (31)
So I can sell it	6% (15)	2% (1)	5% (16)
Other	3% (7)	2% (1)	3% (8)
Form of first sourced cannabis plant(s)[a] % (n)			
Seeds	96% (243)	93% (54)	96% (297)
Cuttings	7% (18)	7% (4)	7% (22)
Seedlings	4% (10)	4% (2)	4% (12)
Juvenile plant	3% (8)	9% (5)	4% (13)
Flowering plant	2% (4)	3% (2)	2% (6)
Other	1% (2)	0	1% (2)
Source[a] % (n)			
Other growers	49% (124)	59% (34)	51% (158)
Online suppliers	44% (112)	22% (13)	40% (125)**
Previously grown plant	40% (102)	29% (17)	38% (119)
Overseas supplier	15% (38)	5% (3)	13% (41)
Cannabis dealer/supplier	5% (12)	12% (7)	6% (19)
'Club' or 'co-operative outlet'	2% (5)	2% (1)	2% (7)
Darknet marketplace	2% (6)	2% (1)	2% (7)
Physical store	2% (6)	0	2% (6)
Other	4% (9)	5% (3)	4% (12)
Sourced seeds/plants because of cannabinoid levels Yes % (n)	54% (137)	47% (27)	53% (164)
Desired cannabinoid with highest level[c] % (n)			
THC and CBD	42% (107)	36% (21)	41% (128)
THC	36% (91)	45% (26)	38% (117)
CBD	15% (38)	9% (5)	14% (43)
I'm not sure	5% (13)	10% (6)	6% (19)
Other cannabinoid	2% (4)	0	1% (4)
Share with family/friends/other growers Yes % (n)	62% (157)	43% (25)	59% (182)*
Amount of home cultivated cannabis consumed per day[b] (grams) median (IQR)	1 (0.3-2)	1 (0.1-2)	1 (0.2-2)

Table 4. Behaviours and motivations for cultivation. Asterix indicate Chi-squared or Fisher's exact tests of independence between current and past cultivators: * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.0$. Some percentages may not total 100% due to rounding. [a]Multiple response-style question, percentages will not equal 100%. [b]Excluded missing values ($n = 2$). [c]THC: Δ^9-tetrahydrocannabinol; CBD: cannabidiol.

were more likely to report sourcing their cannabis seeds from online suppliers, and a higher proportion of them reported sharing cannabis with family, friends and other growers compared to past cultivators.

A large majority (96%) of cultivators grew their first cannabis plant from seed, and mainly sourced their first plant from other growers (51%) or online suppliers (40%). Over half (59%) of cultivators had shared their cannabis with family, friends, and other growers.

Just over half (53%) intentionally sourced their seed or plant in anticipation of certain cannabinoid concentrations (e.g., high THC or cannabidiol (CBD)). Most (41%) cultivators desired their plant to be highest in THC and CBD, while only high THC was the second most (38%) desired.

Cultivation practices

The cultivation practices over the past 12 months of current cultivators ($n = 253$) are reported in Tables 5 and 6.

Cultivators attempted to grow a median of four plants (IQR:3–8), with four plants (IQR:2–6) successfully harvested. Around 47% of participants attempted to grow, and 31% harvested from, more than four plants, which is the legal limit per household (Fig. 2b). The typical median yield of harvested fresh cannabis plant material was 150 g per plant (IQR:1-600) and 120 g per plant (IQR:40–280) for dry cannabis plant material. Most cultivators (68%) had harvested above the legal limit of 50 g of dry plant material (Fig. 2c). Participants spent a median of $60 (IQR:0-200) on seeds, cuttings or juvenile cannabis plants and $150 (IQR:20–600) on horticultural equipment.

Most cultivators were growing outside (garden or balcony; 51%, 6%, respectively) and 14% were growing inside (dedicated room/cupboard or indoor living space; 12% or 2%, respectively). A small proportion (14%) of cultivators were doing both, growing seedlings indoors which were then planted outdoors. Living soil was the most common growing medium (86%) and 77% of cultivators used growing supplements, such as insecticides, herbicides, fertilisers, and growth promoters. Many (41%) reported using organic products only.

Challenges with cultivation appeared very common, with 86% of cultivators reporting challenges. The most common issues were mould (51%), nutrient deficiency (31%) and spider mites (21%). Some cultivators cited non-horticultural related challenges, such as security issues (13%) or police arrest or seizure (4%).

Most cultivators were converting at least some of their cannabis plant material into other forms with only 21% of participants having never processed their cannabis into another form. Cannabis butters and oils for oral use was the most common (56%, 29%, respectively).

Understanding of, and attitudes towards legislation

Current and past cultivators ($n = 296$) were assessed for their understanding of the current legislation in a series of true/false questions. A large majority of participants accurately identified plant and dried cannabis possession limits (98% and 90%, respectively), and the illegality of using cannabis in public places (93%). However, 14% of participants wrongly believed it was legal to use hydroponics or other means of artificial cultivation while 16% believed it was legal to cultivate around children.

When queried about legal grey areas, 78% of participants agreed that the legal number of plants could yield illegal quantities of cannabis, and 68% of participants affirmed that they could not legally source cannabis seeds, cuttings and/or plants (Fig. 3b). Only around half (53%) of cultivators rated the current legislation as clear (Fig. 3a).

More cultivators (44%) felt that the ACT legislation supported their reasons for using cannabis than not (27%; Fig. 3c). However, around half (53%) of the participants expressed dissatisfaction with the current laws, and despite growing cannabis legally, 52% of participants feared arrest or being charged. A minority (16%) felt that current Federal prescription medicinal cannabis schemes supported their needs.

Most cultivators (63%) stated that their cannabis use had not changed since legislative reform, while 31% used cannabis more frequently. A total of 40 (14%) respondents had been arrested or charged in relation to cannabis, and three arrests occurred after the 2020 legislative reform.

Preferences for future legislation

A majority (86%) of respondents supported exemptions to allow medicinal cannabis patients to drive with THC in their system (Table 7). Similarly, most cultivators (91%) stated that cannabis should be legal for all purposes,

	Median (IQR)	N[a]
Plants grown		
Attempted to grow	4 (3–8)	235
Successfully harvested from	4 (2–6)	235
Yield per plant (grams)		
Dried	120 (40–280)	160
Fresh	150 (1-600)	97
Expenditure ($AUD)		
Sourcing cannabis seeds/cuttings/juveniles	60 (0–200)	217
Horticultural equipment	150 (20–600)	215

Table 5. Number of plants grown, yield and expenditure by current cannabis cultivators. [a]Illogical responses and missing values removed, see Methods.

	% (*n*/253)
Main grow location	
Garden	51% (128)
Seedlings grown indoors, then planted outdoors	14% (36)
Dedicated room/cupboard	12% (30)
Greenhouse or protected outdoor area	9% (23)
Balcony	6% (14)
Garage	5% (13)
Indoors in a living space	2% (6)
Other	1% (3)
Growing medium	
Living soil (e.g., potting mix, compost, dirt)	86% (217)
Hydroponics (e.g., deep water culture, drip systems, perlite, foam)	12% (30)
Aeroponics (e.g., nutrient mist)	0% (0)
Other	2% (6)
Use of insecticides, herbicides, fertilisers, growth promoters	
Organic products	41% (104)
Both organic and chemical products	28% (71)
I do not use any growing supplements	23% (59)
Chemical products	3% (8)
Other	4% (11)
Level of concern about contaminants (total $n = 311$)	
Not at all	46% (117)
A little	38% (97)
Not sure	5% (12)
Quite a bit	8% (20)
A great deal	3% (7)
Cultivation challenges[a]	
Mould	51% (128)
Nutrient deficiency	32% (81)
Spider mites	31% (78)
Rot	29% (72)
Aphids/soft-bodied pests	29% (74)
Failing to thrive outdoors	26% (65)
Security issues (e.g., theft)	13% (34)
Failing to thrive indoors	14% (36)
Root problems	13% (34)
Arrest or seizure by police	4% (9)
Other	9% (22)
No answer	15% (36)
Ever converted plant matter to other forms?[a]	
Cannabis butter (oral use)	56% (141)
Cannabis oil (oral use)	29% (74)
No, I have never processed cannabis into another form	21% (54)
Cannabis tincture (oral use)	23% (57)
Cannabis sweets	18% (45)
Hashish	15% (39)
Cannabis balm (topical use)	13% (32)
Cannabis oil (topical use)	8% (19)
Dissolved into drinks	6% (14)
Other	6% (16)

Table 6. Technical cultivation practices of current cannabis cultivators. Some percentages may not total 100% due to rounding. [a]Multiple response-style question, percentages will not equal 100%.

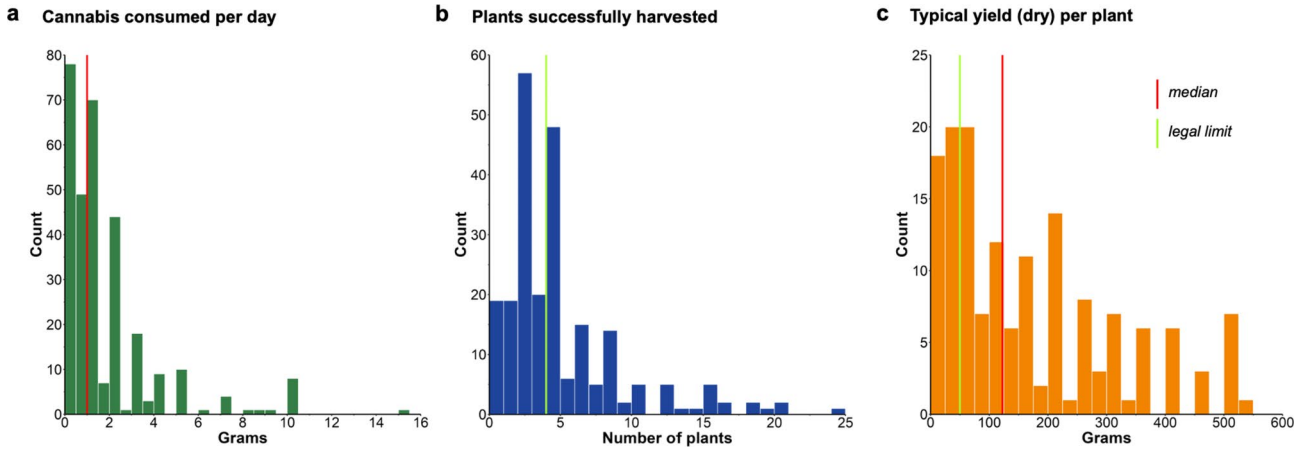

Fig. 2. Cannabis-use and cultivation practices of legal cannabis cultivators. (**a**) Amount, in grams, of home-cultivated cannabis consumed on a typical day, bin size = 0.5 g, $n = 311$ (3 responses > 15 g not shown); (**b**) Number of plants successfully harvested from in the last 12 months, bin size = 1, $n = 235$ (5 responses > 25 plants not shown); (**c**) Typical yield, in grams, of dry plant material per plant, bin size = 25 g, $n = 160$ (7 responses > 600 g not shown). Red lines indicate the median while green lines indicate the current legislative limit in the ACT (in the case of (B), the median and the limit are the same).

with only 6% preferring legality for medicinal purposes only. Most cultivators (54%) endorsed a modest legal limit for the number of plants per person (0–5) with only a minority (15%) desiring no limit. However, a substantial number of participants (40%) desired no limit for harvested plant material amounts, with the current limit of up to 150 g being the second most preferred option (24%). A large majority (92%) of cultivators supported the sale of over-the-counter CBD products.

Phytocannabinoid content of home-cultivated cannabis

A total of 71 cannabis samples ($n = 43$ respondents submitted one sample, $n = 14$ submitted two samples) were analysed for phytocannabinoid content (Fig. 4a). All cannabinoids are reported as a total of their neutral and carboxylic acid conjugates (see Methods).

The most prevalent phytocannabinoid was THC_{total}, with a mean THC_{total} concentration of 8.99 ± 0.51% w/w (Fig. 4a). The second and third most prevalent phytocannabinoids were CBD_{total} and CBG_{total} with mean total concentrations of 0.55 ± 0.22% w/w. and 0.49 ± 0.05% w/w, respectively. Only five samples contained > 1% CBD_{total} and three of these samples had < 1% THC_{total}. The other two had roughly equivalent concentrations of both.

Linear regressions were used to investigate if specific cultivation techniques led to higher concentrations of THC_{total}. There was no significant association between use of fertilisers and concentrations of THC_{total} ($F_4 = 2.262$, $p = 0.073$). However, THC_{total} was correlated with growing location ($F_7 = 2.356$, $p = 0.034$) and growing media ($F_1 = 5.773$, $p = 0.019$). Growing cannabis in a dedicated room or cupboard led to higher amounts of THC_{total} when compared to growing outdoors in a garden ($p = 0.004$), garage ($p = 0.042$), growing seedlings indoors than planted outdoors ($p = 0.001$), and 'other' ($p = 0.027$). Growing cannabis in a greenhouse (or other protected area where plants are grown) also led to higher THC_{total} concentrations when compared to growing in a garden ($p = 0.015$), growing seedlings indoors than planted outdoors ($p = 0.005$) or 'other' ($p = 0.032$). Cultivators who cultivated their cannabis in living soil also were more likely to have higher THC_{total} concentrations, when compared to hydroponics ($p = 0.043$).

Cultivators who submitted a sample were asked which phytocannabinoid they presumed was in their sample ($n = 69$). Half (52%, $n = 27$) presumed THC to be the most prevalent and all, but one, were correct in their presumption. A further 22% of cultivators presumed their sample to contain high levels of both THC and CBD, and only one was correct. Only three cultivators thought their sample to be prevalent in CBD, and zero were correct.

Contaminant content of home-cultivated cannabis

A total of 71 cannabis samples were analysed for heavy metals, 62 for mycotoxins, and 55 for pesticides. Samples were benchmarked against Australian TGO93 standards, with 66 (92%) samples falling under the contaminant thresholds for heavy metals, mycotoxins and pesticides.

Three different pesticides were detected in quantities exceeding the TGO93 limits. Four of the submitted cannabis samples exceeded the TGO93 limit for fluvalinate (0.05 mg/kg), and one sample exceeded the limit for methamidophos (0.05 mg/kg). One sample exceeded the New Zealand limit for bifenthrin (0.1 mg/kg)[39]; however, bifenthrin no longer appears on the Australian TGO93 list.

Trace levels of at least one heavy metal were found in 66 samples; however, these did not exceed TGO93 limits. Most (64) submitted cannabis samples contained trace levels of lead, and just under half contained trace levels of cadmium (Fig. 4b). There were 13 samples containing detectable levels of arsenic, one of which

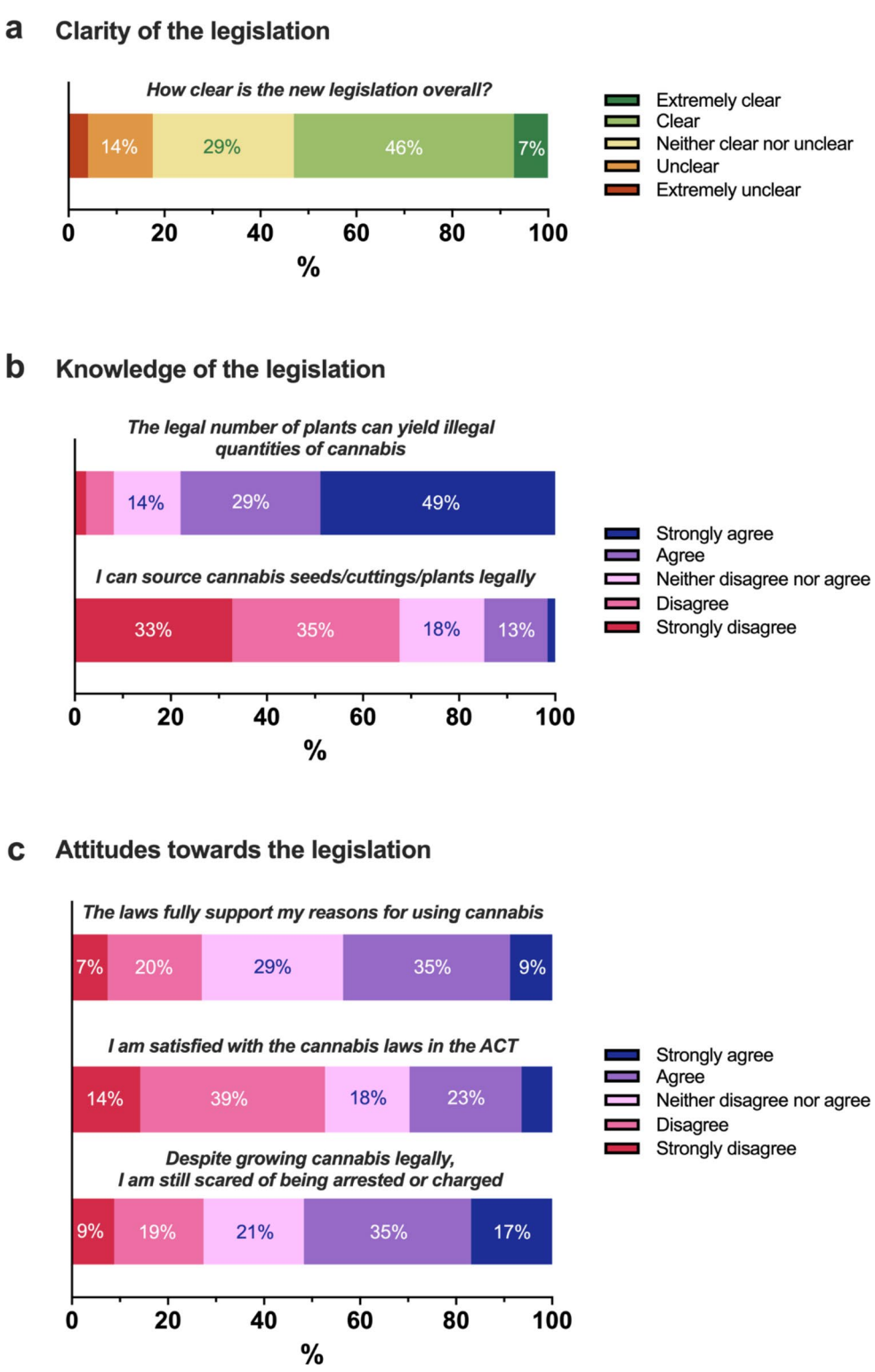

Fig. 3. Attitudes of ACT cannabis cultivators in relation to the 2020 legislation. (**a**) Clarity of, (**b**) Knowledge of, and (**c**) Attitudes towards, the legislation. Unlabelled cells are < 7%. $n = 296$.

contained 6.3 mg/kg and exceeded the TGO93 limit (3 mg/kg; Fig. 4b). Mercury was detected in six samples but did not exceed the TGO93 limit.

None of the cannabis samples submitted contained any of the mycotoxins tested: aflatoxin BI, B2, G1, G2 or ochratoxin A.

	Total ($n=296$)
Do you support legal exemptions for medicinal cannabis patients to drive with THC in their system? Yes % (n)	86% (254)
What do you believe should be the legal limit of cannabis plants for each grower in the ACT? % (n)	
0	0
0–5	54% (161)
5–10	27% (79)
>20	4% (11)
No limit	15% (45)
What do you believe should be the legal amount of dried cannabis that can be possessed by individuals in the ACT? % (n)	
0 g	0% (1)
0–150 g	24% (70)
150–300 g	15% (44)
300–500 g	22% (64)
No limit	40% (115)
What do you believe should be the legal status of cannabis, Australia-wide? % (n)	
Cannabis should be legal for all purposes	91% (270)
Cannabis should be legal for medical purposes only	6% (19)
Cannabis should be illegal for all reasons	1% (4)
Uncertain	1% (3)
I support CBD products being sold over-the-counter % (n)	
Strongly disagree	1% (2)
Disagree	2% (6)
Neither disagree or agree	5% (16)
Agree	25% (73)
Strongly agree	67% (199)

Table 7. Preferences around future cannabis legislation. Some percentages may not total 100% due to rounding.

Discussion

The CAN-ACT study examined the experiences, attitudes and practices of cannabis cultivators in the wake of legislative changes in the ACT decriminalising cultivation and possession. Our analysis complements other sources that speak to the effect of these legislative changes, such as the qualitative interviews with a small sample of ACT cultivators reported by Barrett, et al.[15] shortly after the legislative change, as well as the 2024 review of the legislation conducted by the ACT Government[40]. Also relevant is the National Drug Strategy Household Survey (NDSHS) 2022–2023, which indicated that cannabis use in the ACT population remained stable (8.7% prevalence over 12 months) following the January 2020 legislative changes, a lower prevalence than the national average of 11.5%[12]. Perhaps unsurprisingly, the NDSHS 2022–2023 survey also shows a higher proportion of cannabis cultivators amongst cannabis users in the ACT (12.4%) relative to the Australian national average (3.6%). The results presented here offer a more granular understanding of ACT cannabis cultivators and their experiences, attitudes, and practices, as well as providing a detailed chemical analysis of the cannabis that they are growing.

Who is growing cannabis in the ACT?

Respondents were primarily small-scale cannabis cultivators who used cannabis for non-medicinal (36% of the sample) or dual reasons (42%). In relation to the Global Cannabis Cultivation Research Consortium (GCCRC) project, which surveyed small-scale cannabis cultivators globally around ten years ago, the cohort of cultivators captured here were older than illicit Australian cannabis cultivators in the GCCRC (median 35 years)[41]. Our results also show cultivators being far older than those using cannabis in the ACT[12].

While home-cultivated cannabis was predominantly used to self-supply for non-medicinal reasons, there was large proportion of respondents cultivating cannabis that was 'medicinal' in nature. In fact, more cultivators identified medicinal-use as a motivation for cultivation (61%) than directly identified their cannabis use as being medicinal only (13%) or both medicinal and non-medicinal (36%). Indeed, a survey of Australians using prescribed cannabis products indicated consumers using a proportion of their product for non-medicinal reasons[4]. Blurred distinctions between medicinal vs. non-medicinal cannabis use have been discussed in previous literature, and is in flux across individuals, cultures and class[42–45]. Future cannabis policy should consider the utility of these distinctions[46].

A key motivation for the legislation was to reduce burden on the judicial system and provide an alternate, decriminalised pathway to consuming cannabis[10]. However technical and logistical issues may prevent exclusive use of home-grown supplies. Cultivators reported consuming a median of 1 gram of their home-grown cannabis on a typical day they used, meaning a single harvest from two plants (the legal limit) would not supply enough

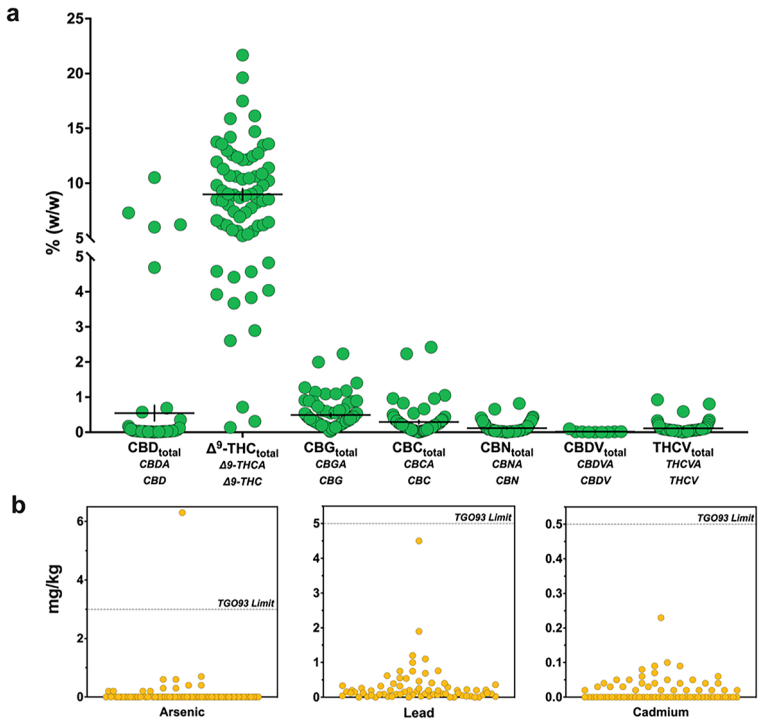

Fig. 4. Chemical analysis of home-cultivated cannabis samples. (**a**) Phytocannabinoid content of individual samples. Horizontal line representing mean % weight/weight (w/w) ± SEM ($n = 71$). Total % (w/w) represents combined neutral and carboxylic acid conjugates. Data presented as individual values % weight/weight(w/w) of total plant matter ($n = 71$). (**b**) Concentrations of the three most commonly detected heavy metals: arsenic, lead and cadmium relative to Australian standards. Dotted line represents limit to pass TGO93/Ph Eur 2.8.13 standards. *CBDA: cannabidiolic acid; CBD: cannabidiol; Δ^9-THC$_A$: Δ^9-tetrahydrocannabinolic acid; Δ^9-THC: Δ^9-tetrahydrocannabinol; CBGA: cannabigerolic acid; CBG: cannabigerol; CBCA: cannabichromenic acid; CBC: cannabichromene; CBNA: cannabinolic acid; CBN: cannabinol; CBDVA: cannabidivarinic acid; CBDV: cannabidivarin; THCVA: tetrahydrocannabivarinic acid; THCV: tetrahydrocannabivarin.*
Note: % (w/w) for Δ^8-tetrahydrocannabinol, cannabinodiol and cannabichromevarin not shown due to low detection.

cannabis for 20 days of usage per month, based on the median harvest amounts reported (125 g). This is pertinent considering that ACT cultivators captured here are seemingly risk averse, with many preferring home-cultivation to avoid contact with illegal suppliers and to decrease the risk of criminal activity.

Just under half of the ACT cultivators captured here also perceived this home-cultivation to be 'healthier' due to having more control and oversight of the entire growing process. Many cultivators had also converted their cannabis plant matter into orally administered edibles or extracts (e.g. butter or oils), and there is a general perception that they are healthier routes of administration[47,48]. Interestingly, inhaled routes of cannabis consumption were highly correlated with meeting Cannabis Use Disorder (CUD) criteria compared to non-inhaled routes[49]. Our survey did not evaluate the possibility of Cannabis-Use Disorder (CUD) and/or other indicators of problematic use or dependence amongst ACT cultivators. While beyond the scope of this study, future investigations could examine possible links between decriminalisation of cultivation and prevalence of CUD.

Overall, it may seem that ACT cultivators captured here align with the small-scale cannabis growers identified by Hammersvik, et al.[50] (2012), that discouraged risk-averse small-scale growers from expanding into large-scale commercial production. For example, 85% of cultivators noted difficulties with home cultivation (e.g., contending with mould, nutrient deficiency and pests), and it could be that these technical and logistical issues prevent scaling up production. Further, ACT cultivators align with 'ideological growers' identified in previous reports, who distance themselves from illicit drug markets, do not grow for financial gain and some reported growing for 'political or activist reasons'[41,51,52]. Indeed, only 5% of our cohort indicated that they cultivated cannabis to sell it, however it is noted that cultivators who are motivated by supply and profit may be less likely to participate in our survey. It is also telling that the second most common reason for growing was purely because ACT cultivators enjoyed the process of growing cannabis.

Legislation and navigating the 'grey areas'

Respondents readily identified several 'grey areas'[15] in the current legislative approach where well-intentioned behaviour could result in illegal activity. For example, with an average yield of 125 grams per plant and two plants permitted per individual, it appeared that many cultivators exceed the legal gram possession amounts of

fresh (150 grams) or dried (50 grams) plant material. Another obvious concern was that there is no legal means of sourcing seeds or cuttings to initiate cultivation, and the ACT cultivators captured here were cognisant of this.

Most respondents gave cogent responses when asked about how the legislation could be improved. Some limit on the number of plants permitted was generally preferred. In support of this, most cultivators attempted to grow four plants or less at any given time, adhering with the ACT legislative limits (Table 1). Even under illegal conditions, the GCCRC reported that Australian cultivators grew a median of four mature plants, and only 24.4% of that cohort endorsed no restriction on the number of plants[53] (compared to 18% in this current survey). Legal cannabis cultivation in the USA and Canada also finds most cultivators growing within legal parameters[54,55].

ACT cultivators preferred no limit on the amount of dried cannabis possessed by individuals and their reported dry and fresh yields were over the legal limit. Similar to the current results, the GCCRC reported that Australian cultivators harvested a median of 85 g of dry and 285 g of fresh matter per plant[41], also well in excess of ACT limit. Harvest amounts reported here varied considerably across individuals, as yield is likely impacted by a variety of factors such as individual skill/experience, cultivation practices, environmental factors. Importantly, the current legislation does not specify how cultivators might limit their harvest when their legal number of plants yield illegal amounts of cannabis. Our results show 59% of ACT cultivators illegally share their cannabis while 76% convert plant matter into other forms, perhaps to help address this problem[56].

As such, ACT cultivators captured here tended to be dissatisfied with current laws despite feeling somewhat supported by the legislation. A significant proportion of cultivators reported still feeling scared of arrest. This supports findings from qualitative interviews with some ACT cultivators, who stated that vulnerable communities found it harder to navigate 'grey areas' in the legislation, while positive attitudes towards the legislation were more apparent in cultivators with more social privileges and lower chances of interaction with police[15]. It is clear that some refinement in the legislation pertaining to plant and yield limits could mitigate these challenges, particularly as many cultivators grow to avoid illegal activity. Refinement would also better support the initial motivations of the legislation to reduce burden on the judicial system from trivial drug offences.

Do past cultivators use and grow cannabis differently from current cultivators?

Past cultivators were more likely to be younger and start using cannabis earlier than those currently growing. They were also less likely to source their first plant from online suppliers with a higher proportion of past cultivators sourcing their plant from other growers. This describes a type of grower who potentially has less strong motivations and/or skill to grow their own cannabis for personal use, indeed they didn't enjoy the process of growing and felt it was harder to grow cannabis than buy it. As such, they were less motivated to grow to avoid contact with illegal suppliers. It is clear that there is a small population of younger people, some of whom are captured here, where cultivating cannabis is not an accessible or motivating method of sourcing cannabis legally. Future legislation should consider the limitations of the current personal-use model and whether it is equitable for the population.

What kind of cannabis is being grown?

Analysis of phytocannabinoid concentrations revealed a preponderance of THC-dominant cannabis, with only a small minority of samples having a CBD-dominant or a THC: CBD equivalent chemotype. These three main cannabis chemotypes, with THC-dominant cannabis being the most prevalent, is typical of commercial and medicinal markets worldwide[57–59]. Minor phytocannabinoids, such as CBG, CBN and CBC, were present in low to negligible concentrations.

Hydroponics techniques did not lead to higher concentrations of THC_{total} in submitted samples. Current legislation prohibits the use of hydroponics and artificial lighting for personal cannabis cultivation. While there was a small proportion of ACT cultivators (11%) who were using hydroponics to grow cannabis, it could be that the colder climate of the ACT during winter may lead to less-than-ideal conditions for outdoor cannabis cultivation[60,61]. While we did not inquire about climate, 27% of cultivators indicated that one of their cultivation challenges was failing to thrive outdoors. Our results here indicate that cultivating cannabis in protected spaces, such as a room/cupboard or greenhouse, led to higher concentrations of THC_{total} when compared to the most common response of growing in a garden.

However, it is important to consider this alongside the evidence that THC_{total} concentrations observed in the present study (8.99%) were considerably lower than those previously reported in police-seized cannabis from Australia (14.88%)[27] and the United States of America (USA; 13.88% in 2019)[62]. They were also lower than many Australian prescription medicinal cannabis products, where concentrations of 20–30% are common in flower products (median of 23% THC)[63,64]. Given that use of high-potency cannabis can cause unpleasant and undesirable short-term effects and sometimes is associated with adverse mental health outcomes[65–67], low THC concentrations are arguably a positive attribute. It could be that individuals are consuming more of this cannabis to compensate for the relatively low THC content[68,69]. However, previous literature suggests that this is not ocurring in the cohort captured here, as the amount of cannabis used per day reported here is generally lower than that of medicinal and non-medicinal cannabis consumers from the USA and UK[70,71].

Many cultivators expected and desired CBD to be present in their homegrown cannabis to a much greater extent than it was. Similarly, the 'PELICAN study', a survey of Australian parents using illicit cannabis products to treat epilepsy in their children, greatly overestimated the CBD concentrations present[72]. CBD is frequently prescribed in Australia to treat chronic pain, anxiety and sleep difficulties but requires relatively high doses of 300 mg or above for efficacy[73–75]. With only five of 71 samples containing appreciable levels of CBD and many cultivators desiring CBD in their plants, the community could benefit from having access to a legal mechanism to acquire seeds and cuttings with information on phytocannabinoid content and genetics. Further, the ability to being able to analyse the phytocannabinoid content, including THC, of their home-grown product could

be included with the drug checking of pills and powders that is currently permitted in the ACT as a harm-minimisation measure[22,76,77]. Knowledge of CBD and THC content would help consumers titrate their cannabis dosages and avoid unintentional psychoactive effects, particularly when THC is desired. We are aware that some of our respondents are already using their anonymised results to do this[78].

Most cannabis samples tested were compliant with the TGO93 standards that govern the safety of Australian prescription cannabis products. However, some had visible traces of mould, with one participant intentionally sending in a mouldy sample for testing. While we assessed samples for mycotoxins, not all moulds produce them, and our samples were not analysed as per TGO100 (Australian microbiological standard for medicines) as it would have required an additional 25 g of plant material. Our analysis also found trace levels of heavy metals in most samples and isolated cases of pesticides. The impact of such contaminants on human health is of some concern, particularly when cannabis is smoked or vaporised[16,17]. Educational campaigns and horticultural guidance (similar to other plants that are often consumed) across all aspects of cannabis cultivation, drying and storage would help mitigate avoidable harms from contaminated products.

Limitations

Our study is not without limitations. The study population tended to be older, employed, well-educated, urban-dwelling adults with good internet access and high literacy[12] and may not be representative of the broader Australian cannabis-using or -cultivating community. While we attempted to use a broad range of recruitment methods (online, traditional media, in-person events and community word of mouth) to capture a broad range of cultivators, this survey consists of a convenience sample.

Information gathered around the amounts of cannabis harvested and the number of plants may suffer inaccuracy around measurement and/or recall, and participant responses may have been affected by other biases. For example, flippant responses may have been given to only be eligible to submit a cannabis sample or to avoid disclosing incriminating information. We attempted to mitigate this by making the survey anonymous and not collecting IP addresses however the incentive of cannabinoid testing meant that duplicates or fraudulent responses were possible. It is noted that no duplicates were identified in the data and less than a fifth of cultivators submitted a sample.

When engaging with the ACT community online and in-person during recruitment, many potential recruits expressed concerns around anonymity, police prosecution and theft, leading to a low likelihood of participation from certain cultivators. The continuing illegality of cannabis possession, cultivation and trade (including that of seeds) under Australian federal law was a frequent concern. It is well established that either harms and/or benefits from cannabis policy laws impact people in the ACT differently[15], and further research could focus on more vulnerable populations that may not have been well-captured in this current survey.

Conclusion

Overall, the decriminalisation of cannabis cultivation and possession in the ACT appears to support the needs of the community with limited unintended consequences. The results of the survey provide further context to the largely positive findings from the 2024 review of the legislation conducted by the ACT Government[40]. The cannabis being cultivated in the region appears to be lower in THC content than most commercial medicinal cannabis products and, for the most part, free of contamination. That said, it appears that further refinement of the legislation is warranted to prevent unintentional illegal activity by cultivators and to better support public health and harm minimisation measures. Our results indicate that lifting some cultivation restrictions, providing informed and legal access to seeds/cuttings and disseminating resources and guidance for cultivation could be of further benefit to the ACT community.

Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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Author contributions

IM provided conceptualisation and, together with IL, DM, RK, decided on methods. IL, RG, CZ and MBP collected and analysed data. IM and CZ wrote the manuscript and prepared the figures and tables. All co-authors reviewed and contributed to the final version of the paper.

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Declarations

Competing interests

IM has acted as a consultant to Kinoxis Therapeutics and has received honoraria from Althea and Janssen. He is an inventor on several patents relating to novel cannabinoid and non-cannabinoid therapeutics. His

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Additional information

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Correspondence and requests for materials should be addressed to I.S.M.