International Journal of Drug Policy

Growing practices and the use of potentially harmful chemical additives from a web survey of mainly small-scale cannabis growers in 18 countries

--Manuscript Draft--

Manuscript Number:	DRUGPO-D-24-15R2
Article Type:	SI: Global cannabis cultivation
Keywords:	Cannabis cultivation; Marijuana; Policy; online survey; International comparative research.
Corresponding Author:	Simon Lenton, PhD MPsych(clin) MAPS National Drug Research Institute Perth, WA AUSTRALIA
First Author:	Simon Lenton, PhD MPsych(clin) MAPS
Order of Authors:	Simon Lenton, PhD MPsych(clin) MAPS
	Gary Potter
	Davide Fortin
	Ashely Granville
	Jodie Grigg
	Eric L Sevigny
	Chris Wilkins
	Tom Decorte
	Monica Barratt
Abstract:	Background: There is emerging recognition of the risks of harmful chemical pesticides, fertilizers and ‘nutrients’ by cannabis growers. One group of chemicals, Plant Growth Regulators (PGRs), many of which have been banned from food crops for decades, have been found unlisted in a number of fertilizers and supplements marketed at cannabis growers. Methods: This paper predominately uses data from a 2020-21 convenience web survey of mainly small-scale, recent (last 5yrs) cannabis growers from 18 countries (n=11,479). We describe their growing practices and use of chemicals and employ logistic regression to explore predictors of chemical use. We also compare chemical use in our 2020-21 sample with that from our 2012-13 data in the 3 countries (Australia, Denmark, UK) where respondents were asked about their use of growing chemicals in both surveys. Results: In 2020-21, 26% of recent cannabis growers reported use of chemicals. Growers who were at highest odds of using chemicals were male, older, living in urban/cities, not growing for environmental reasons, growing in order to sell, growing where they believed cannabis was legal, and growing under artificial light in soil or non-soil media. We found significant reductions in the proportions of our samples who reported using chemical fertilizers in the 3 countries where we collected data in both waves. Conclusion: Growers using soil and artificial light comprised over half of all the chemical users in the sample. Efforts at informing and educating growers about the problems of chemical fertilizer, nutrient and pesticide use should include all growers including those who grow in soil under artificial light. Possible explanations for the apparent decrease in chemical use from our 2012-13 to 2020-21 samples are discussed. Stricter regulation of the legal cannabis fertilizer market is required to empower growers to reduce the toxicity of cannabis they grow, distribute and consume.

The Editors

IJDP Special section on cannabis cultivation,

Dear editors,

Please find attached for your consideration a revised version our manuscript DRUGPO-D-24-15 R2 entitled *Growing practices and the use of potentially harmful chemical additives from a web survey of mainly small-scale cannabis growers in 18 countries* which is being submitted for the special section on Cannabis Cultivation edited by Jason Grebely.

Regards,

Simon Lenton.

On behalf of all authors.

13 November 2024

Revision Notes DRUGPO D-24-15.

	Reviewer / Editor comments	Responses
	2.2/2.4/3.2 R3 said that without knowing whether all/most chemicals used were harmful, the analysis in the paper will to some extent be undermined. The authors respond by saying it's impossible to know whether products would be harmful (and their explanation is good), but they do not address what is critical to this comment, which is that not knowing undermines the analysis. The authors need to respond in their revision to this. While this criticism of the paper could potentially be seen as 'fatal', it does not fully have to undermine the paper. The authors need to do their best to justify their work in this light. I think a few sentences should probably do it.	RESPONSE: We accept that this needs more clarification and justification. ACTION: The previous para in the limitations stated: "As we noted above, for practical reasons, we did not ask growers to identify the brands of fertilizers which they used. We acknowledge that this may be seen as an omission and in our future work we will continue to explore how we can usefully get more information on which products growers are using and with, better data on product contents, be able to draw stronger conclusions on the use of noxious chemicals." (p.18) We have edited the text thus: "As we noted above, for practical reasons, we did not ask growers to identify the brands of fertilizers which they used. We acknowledge that this is an important limitation of our work as we are not able to definitively say whether those respondents using chemical nutrients and fertilizers were using products containing PGRs, pesticides and other compounds which have been shown to be harmful to health. However, as we have noted, the presence of PGRs and other toxic chemicals in growing cannabis nutrients and fertilizers and being found in cannabis in the market continues to be an issue in many countries (Drug Information and Alerts Aotearoa New Zealand (DIANZ), 2021; Dugar, 2022; Dutch Passion, 2023; Lagrasso, 2021; Ledger, 2022; Lu, 2022; Stumper, 2022; Weedhack Staff writer, 2023). Furthermore, the way the question was asked, as explained in the Methods, does mean that it is in the 'chemicals' group where potentially harmful nutrients, fertilizers and pesticides will be found. Consequently, while the findings are not definitive regarding risky chemical use, they do point to which growers could be targeted with interventions to raise the issue to reduce risk. Beyond this, in our

		future work we will continue to explore how we can usefully get more information on which products growers are using and with, better data on product contents, be able to draw stronger conclusions on the use of noxious chemicals." (Pp18-19)
2.1	In respect of the justification for the MV analysis, the revisions here are welcome. However, the question of the rationale for the MV analysis remains insufficiently articulated, given that this had previously been identified as connected to identifying growers for intervention/education.	RESPONSE: The primary reason for undertaking a multivariate analysis was to deal with the problems caused by highly correlated variables which potentially are associated with chemical use. We did explain this in the methods section, here: 'Bivariate predictors of the use of chemical fertilizers, supplements, and insecticides were subsequently subjected to multivariate analysis with a binomial logistic regression to explore their unique relationship with the use of chemicals where inter-correlation was accounted for.' (Pp.9-10) ACTION: We have added the following text after the above sentence: 'That is, for example, if both growing indoors and grow method (including hydroponic growing) where shown to be highly predictive of use of chemicals by univariate analysis, the multivariate analysis will show which of those highly correlated predictors was responsible for the greatest amount of variance in use of chemicals to help inform interventions to reduce risk.' (p.10)

Growing practices and the use of potentially harmful chemical additives from a web survey of mainly small-scale cannabis growers in 18 countries

SIMON LENTON[1], Gary Potter[2], Davide Fortin[3], Ashely Granville[4], Jodie Grigg[1], Eric Sevigny[5], Chris Wilkins[6], Tom Decorte[7] Monica Barratt[8,9]

1. National Drug Research Institute, enAble Institute, Curtin University, Australia
2. Lancaster University Law School, UK
3. Aix Marseille Univ, INSERM, IRD, SESSTIM, Sciences Economiques & Sociales de la Santé & Traitement de l'Information Médicale, ISSPAM, Marseille, France
4. School of Criminal Sciences, University of Lausanne, Switzerland.
5. Department of Criminal Justice and Criminology, Georgia State University, USA.
6. SHORE & Whariki Research Centre, College of Health, Massey University, NZ.
7. Institute for Social Drug Research (ISD), Ghent University, Belgium.
8. Social Equity Research Centre and Digital Ethnography Research Centre, RMIT University, Melbourne, Vic, Australia
9. National Drug and Alcohol Research Centre, UNSW Sydney, NSW, Australia

Growing practices and the use of potentially harmful chemical additives from a web survey of mainly small-scale cannabis growers in 18 countries

Key words: Cannabis cultivation, Marijuana, Policy, Online survey, International comparative research

ABSTRACT

Background: There is emerging recognition of the risks of harmful chemical pesticides, fertilizers and 'nutrients' by cannabis growers. One group of chemicals, Plant Growth Regulators (PGRs), many of which have been banned from food crops for decades, have been found unlisted in a number of fertilizers and supplements marketed at cannabis growers.

Methods: This paper predominately uses data from a 2020-21 convenience web survey of mainly small-scale, recent (last 5yrs) cannabis growers from 18 countries (n=11,479). We describe their growing practices and use of chemicals and employ logistic regression to explore predictors of chemical use. We also compare chemical use in our 2020-21 sample with that from our 2012-13 data in the 3 countries (Australia, Denmark, UK) where respondents were asked about their use of growing chemicals in both surveys.

Results: In 2020-21, 26% of recent cannabis growers reported use of chemicals. Growers who were at highest odds of using chemicals were male, older, living in urban/cities, not growing for environmental reasons, growing in order to sell, growing where they believed cannabis was legal, and growing under artificial light in soil or non-soil media. We found significant reductions in the proportions of our samples who reported using chemical fertilizers in the 3 countries where we collected data in both waves.

Conclusion: Growers using soil and artificial light comprised over half of all the chemical users in the sample. Efforts at informing and educating growers about the problems of chemical fertilizer, nutrient and pesticide use should include all growers including those who grow in soil under artificial light. Possible explanations for the apparent decrease in chemical use from our 2012-13 to 2020-21 samples are discussed. Stricter regulation of the legal cannabis fertilizer market is required to empower growers to reduce the toxicity of cannabis they grow, distribute and consume.

[298 words]

Introduction

In 2021, worldwide, 219 million people are estimated to have used cannabis in the past 12 months (UNODC, 2023). In the past 10 years, cannabis use has been legalized in a number of countries for medical use and a handful of countries for non-medical use, but non-medical use remains illegal in most parts of the world and subject to the UN conventions (Decorte, Lenton, & Wilkins, 2020). Over the last 40 years cannabis cultivation techniques have changed substantially, with increased indoor growing under lights and the use of hydroponic methods. These changes have facilitated indoor domestic cultivation in many developed countries, which has reduced reliance on cannabis imported from 'traditional producer countries' (Decorte & Potter, 2015). Over 2012-2019, international data indicates that the increase in indoor cannabis cultivation was greater than that of outdoor cultivation, with 65 countries that reporting indoor cannabis cultivation to UNODC in 2019 (UNODC, 2021).

Previous research by our research collaboration based on data from 1722 growers in 3 countries (Australia, Denmark, and the UK) showed that many cannabis growers use 'nutrients', fertilizers and other horticultural chemical products, hereafter termed 'chemicals', that are marketed towards cannabis growers, sold online and in 'grow shops' (Lenton, Frank, Barratt, Potter, & Decorte, 2018). These products, are manufactured by a legal industry, estimated to be worth USD 201.86 million in 2022 (Singh, 2023), that flies under the regulatory radar. They have names designed to appeal to cannabis growers, such as 'Big Bud', 'Bloombastic', 'Nirvana', 'Monsta Bud' and 'Dutch Master' (Lenton, et al., 2018). This research suggested that, in many cases, the labels on these products misrepresent their true contents (Lenton, et al., 2018), masking the fact that many products contain hazardous chemicals, notably pesticides and Plant Growth Regulators (PGRs) (Hermes, 2011; Sirius, 2016). PGRs are used in illegal cannabis cultivation because they produce smaller plants with a higher concentration of larger flowers or 'buds' (Subritzky, Pettigrew, & Lenton, 2017). Buds are the part of the cannabis plant with the highest tetrahydrocannabinol (THC, the main psychoactive compound) content and comprise the bulk of cannabis sold and consumed for its psychoactive properties. PGRs increase the yield of buds per plant and per unit of growing area (Manic Botanix, undated; Subritzky, et al., 2017), making them particularly attractive to indoor growers and those that want to sell their cannabis, even though they produce buds with fewer terpenes and cannabinoids and, consequently, lower potency (Stumper, 2022).

Health concerns

Most PGRs have been banned in mainstream legal agriculture for decades due to their toxicity (Hermes, 2011). Notable PGRs, daminozide (Alar) and paclobutrazol, have been found unlabelled in nutrient solutions targeting cannabis growers and sold online and in grow shops and hydroponic equipment stores in the US (Hermes, 2011). Paclobutrazol has been shown to affect neurotransmitter systems in rodent models (e.g. Xu & Yang, 2020), disrupt spermatogenesis, affect development in several fish species, and produce toxicity, likely via accumulation in the brain (Li, et al., 2012). However, little is known about the health consequences to humans from chronic exposure (Montoya, Conroy, Vanden Heuvel, Pauli, & Park, 2020) as would be seen among people who regularly use cannabis. Daminozide is classified as a Group B2 Probable Human Carcinogen (National Center for Biotechnology Information, 2022). Paclobutrazol has been banned from use on food, and as a consequence, no maximum levels of exposure have been established for agricultural products in the US (Massachusetts Department of Agricultural Resources, 2012). Evidence suggests that some 70% of the chemical residues (including paclobutrazol) on plant material can be transferred to mainstream smoke (Sullivan, Elzinga, & Raber, 2013). Furthermore, burning pesticide chemicals while smoking can produce highly toxic pyrolysis products (Atapattu & Johnson, 2020).

So, while some people who use cannabis choose to grow their own plants to produce 'healthier' cannabis (Potter, et al., 2015), many growers using these nutrient and fertilizer products may be unwittingly introducing hazardous chemicals into the cannabis they grow, consume and supply to others due to inaccurate labelling which claims the products to be 'natural', when many contain these toxic chemicals. Indeed, cannabis plants readily absorb toxins and are recognized as *hyperaccumulators* of pesticides, toxins, heavy metals, radioactive elements and hydrocarbons and for that reason are proposed as ideal plants for phytoremediation of contaminated soils and environments (Bengyella, Kuddus, Mukherjee, Fonmboh, & Kaminski, 2022). Hyperaccumulators are plants which can absorb and accumulate heavy metals in their leaves and other above-ground sections at values exceeding specific metal thresholds (Sytar, Ghosh, Malinska, Zivcak, & Brestic, 2021)

Advocates within the cannabis growing and using community in North America (e.g. Integral Hydroponics, 2015; Manic Botanix, undated; Sirius, 2016) were instrumental in raising concerns about these products and prompting regulatory interest. Early testing of cannabis products in both emerging legal and established 'tolerated' cannabis markets revealed high rates of contamination with these chemicals, for example in Californian medical cannabis patients (Sullivan, et al., 2013), many of whom were at increased vulnerability due to their illnesses (McPartland & Pruitt, 1997), and 'cannabis coffeeshops' in the Netherlands (Venhuis & van de Nobelen, 2015). Subsequently, millions of dollars of legal cannabis products were destroyed in Canada (Robertson, 2017) and Colorado (Migoya, 2017) because they were contaminated with myclobutanil, a fungicide that has been found to produce cyanide on combustion (Health Canada, 2017). Many commercial formulations of pesticides targeted at cannabis growers comprise a mix compounds from a variety of chemical classes in one product (Taylor & Birkett, 2020), and can be detected in cannabis often at levels well in excess of those allowable in any legally available agricultural product (Voelker & Holmes., 2015).

Regulation

Pesticides, fertilizers and nutrient products are subject to legal regulatory control in many countries, yet there are reasons to doubt the regulatory effectiveness in the cannabis growing focussed market, particularly where cannabis cultivation is illegal. For example, in California in 2010 it was reported that hydroponic stores had repackaged pesticides (e.g. bifenazate and abamectin) for sale to cannabis growers, that were only approved for use on landscape plants but not on plants grown for human consumption (McPartland & McKernan, 2017). In Australia, chemicals such as PGRs must be registered with the Australian Pesticide and Veterinary Medicine Authority (APVMA) before they can be legally supplied via brick-and-mortar stores or online retailers, with fines enforced for supply of unregistered products. While regulations exist 'on the books' it is unclear how rigorously they are enforced. In many countries, even if those who illegally grow cannabis want to ensure they produce contaminant-free cannabis for themselves and their peers, poor product labelling makes it hard to identify a regulatory breach. Furthermore, where a grower in an illegal market determines that their nutrient supplier is selling products in breach of the regulations, it is unlikely they will risk identifying themselves to the authorities by registering a complaint. Additionally, toxicological studies submitted as part of product registration rarely consider all potential end-market uses, such as combustion that will occur as part of cannabis consumption. Finally, the capacity for authorities to effectively monitor the large volume of online sales, many of which may be cross-border, is questionable.

Cannabis growing practices

There are many online sources of information on cannabis growing and use of different growing locations (indoor and outdoor), grow media (soil and non-soil), lighting (sunlight and various forms of artificial light) and other equipment (Lenton, et al., 2018). There are also various techniques and different garden styles which are used to maximize the exposure to light and produce the highest yield of flowering heads. These include hydroponic and related cultivation techniques (e.g., ebb and flow watering, deep water culture, aeroponics) and methods of plant training (topping, training, pruning, etc.) (Lenton, et al., 2018).

Our previous study, which asked growers in Australia, Denmark and the UK about their growing practices, found that unsurprisingly, because of climate and open space, Soil and Sunshine (Soil – Natural Light; S-NL) growing was more common in Australia (55.6%) than in Denmark (44.7%) and the UK (10.3%), while Soil and Artificial Light (S-AL) growing was more common in the UK (67.7%) and Denmark (44.7%) compared to Australia (28.5%). Growing hydroponically (Non Soil – Artificial Light; NS-AL) was reported by a higher proportion of respondents in the UK (22.0%) comparted to Australia (15.9%) or Denmark (10.7%). There were also significant differences between countries across most growing locations, with most of these seemingly associated with climate and issues of space and population density in the three countries. Chemicals were significantly more likely to be used by respondents from the UK (61.0%) and Australia (45.3%) than those from Denmark (34.6%). Biivariate comparisons suggested use of chemicals was significantly more common among those: who grew to sell, male growers, grew using artificial lights (NS-AL and S-AL), had a growing area of 3 square meters or less, communicated with growers online, and were slightly older than those who did not. However, multivariate analysis suggested that the only unique predictor of the use of chemicals was grow method. Specifically, compared to those who grew in soil and sunshine (S-NL), respondents who grew in soil under artificial lights (S-AL) were at 2.86 greater odds of using chemicals and those employing hydroponic methods (NS-AL) were at 11.89 greater odds of using chemicals.

The current paper

This paper describes the cannabis growing practices of mainly small-scale cannabis growers in 18 countries, with particular focus on their self-reported use of chemicals (chemical fertilizers, pesticides and 'nutrients') and exploring the predictors of chemical use. Presenting results on growing practices (separate to chemical use) is important because since our 2012-13 data collection (Lenton, et al., 2018) there have been developments in equipment (e.g. LED lighting) and growing practices are key variables likely to be related to chemical use. We also compare chemical use in our 2020-21 sample with that from our 2012-13 data (Lenton, et al., 2018) in the 3 countries (Australia, Denmark, UK) where web survey respondents were asked about their use of growing chemicals in both surveys. These issues have clear policy implications regarding regulation in both the expanding legal cannabis market and the grey market for pesticides, fertilizers and nutrients targeting people who grow cannabis. They are also relevant to individual cannabis growers regarding the choices they make about what fertilizers and nutrients they use on their plants, and people who use cannabis making informed choices about the cannabis they consume.

Method

Data comprised responses to the International Cannabis Cultivation Questionnaire (ICCQ 2), a convenience web survey developed by the Global Cannabis Cultivation Research Consortium (GCCRC) (2023) to measure and compare patterns of mainly small-scale cannabis cultivation across different countries (Global Cannabis Cultivation Research Consortium, 2023). The data protocol is registered and available (Lenton, et al., 2023). The study method was closely based on that described in detail from the earlier phase 1 survey (ICCQ 1) conducted in 2012-13 (Barratt, et al., 2012; Barratt, et al., 2015) in 11 countries. In the most recent survey, using the ICCQ 2, data were collected in 18 countries in 12 languages, from August 2020 to September 2021. We used a broad-based recruitment strategy to maximize the heterogeneity of respondents including an international project website (www.worldwideweed.nl), Facebook groups, Twitter, online forums, drug policy influencers, mainstream media, street press advertisements, and flyers distributed at festivals, grow shops and university campuses. Once directed to the project website (www.worldwideweed.nl), potential respondents could choose the survey and language associated with their country of residence (see also Barratt, et al., 2015). Eligibility criteria for inclusion in the analysis were that the participants had to be at least 18 years of age, had grown cannabis during the past five years, and had completed at least 50% of the ICCQ 2 core questionnaire (Global Cannabis Cultivation Research Consortium, 2023). Where required, ethical approval was sought and granted in each of the participating countries (usually at the institutions of the lead GCCRC member for that country). As we have described elsewhere (Barratt, et al., 2012), IP addresses were not collected because familiarity with the target group and piloting emphasized the importance of anonymity and this was noted in ethics committee applications. A duplicate cases analysis indicated only 49 duplicates (0.4% of cases). These were removed from the data set resulting in the final N of 11,479 eligible responses.

The ICCQ 2 included 40 core questions on: experiences with growing cannabis; methods (including use of fertilizers, pesticides and other chemicals) and scale of growing operations; reasons for growing; personal use of cannabis and other drugs; demographic characteristics of growers; contact with the criminal justice system, and participation in cannabis and other drug markets. In addition to the core questionnaire, specific optional and specialized modules were offered to participants in different countries based on perceived relevance and topicality.

Specifically, in the current survey, respondents were asked: “What fertilizers, supplements (e.g. growth agents, bud stimulators) or insecticides do you typically use?” The response options (unnumbered in the online survey) were: (1) Organic fertilizers, supplements or insecticides; (2) Chemical fertilizers, supplements or insecticides; (3) Both organic and chemical fertilizers, supplements or insecticides; (4).

I do not use any fertilizers, supplements or insecticides; and then Don't know or Prefer not to say options. Respondents who answered 2 or 3 above were coded as having used chemical fertilizers for this analysis.

Unlike in the 2012-13 survey, we did not ask growers to specify the brand of fertilizer they used. While on face value this would seem important to identify use of chemicals such as PGRs, in our previous survey we found incomplete labelling and failed to find products listed on online organic certification systems in various countries prevented us from determining which products contained PGRs and which did not (Lenton, et al., 2018). Furthermore, hydroponics and cannabis toxicology experts we consulted expressed the opinion that identifying PGRs via brand names was an impossible task due to inadequate or mislabelling (Lenton, et al., 2018). Further, as this question was asked to all respondents in the core questionnaire, rather than in an optional module as in 2012-13, time and space constraints precluded it.

The current analysis focuses on respondent demographics, methods and scale of growing operations, and reasons for growing from the ICCQ, along with questions from the optional Growing Methods module which included questions addressing typical type of lighting and other equipment used, where growing took place, hours per week spent on growing, weeks to produce a crop and the typical number of plants grown. Overall, the Growing Methods module was offered to respondents in 10 Countries (Australia, Austria, Canada, France, Georgia, Germany, Italy, Switzerland, UK, USA) and completed by a subsample of 5564 individuals. There was a further module targeting harvesting and processing, but as the countries completing the Growing and Harvesting modules were not the same, this data will be presented in a separate paper.

Analysis

For bivariate analyses (chi square for categorical variables, ANOVA, and t-test for continuous variables) a conservative alpha level of $p < 0.01$ was applied to account for the possibility of type 1 error due to multiple comparisons.

Bivariate predictors of the use of chemical fertilizers, supplements, and insecticides were subsequently subjected to multivariate analysis with a binomial logistic regression to explore their unique relationship with the use of chemicals where inter-correlation was accounted for. That is, for example, if both *growing indoors* and *grow method* (including hydroponic growing) where shown to be highly predictive of use of chemicals by univariate analysis, the multivariate analysis will show which of those highly correlated predictors was responsible for the greatest amount of variance in use of chemicals to help inform interventions to reduce risk. Multivariate logistic regression with cluster robust standard errors (by country) (Long & Freese, 2014) was employed to analyze the use of chemical fertilizers, controlling for a range of theoretically and empirically relevant covariates. To assess logistic regression model fit, we consider a C-statistic of $0.7 \leq C < 0.8$ to be acceptable and $0.8 \leq C < 0.9$ to be excellent (Giancristofaro & Salmaso, 2003). We also examined the presence of multicollinearity using the variance inflation factor (VIF), where VIF < 3 is good and VIF < 5 is acceptable. When presenting the results of the logistic regression analyses, we report odds ratios (ORs) in the table. We adopted a $p < .05$ criterion for determining statistical significance of predictors. Discussion of specific effects implies holding all other variables constant.

Decisions as to what variables were included in the logistic regression were based on an exploration of bivariate relationships between the predictors and criterion variable (Chemical use yes/no) (see Table 5) and what was known from other analyses including our own (Lenton, et al., 2018) and comprised a different and larger set of potential predictors than that earlier work. Most independent variables in the logistic regression were categorical, rather than continuous. But for ease of interpretation, where it made conceptual sense, both continuous and categorical variables with more than two values were dichotomized or trichotomized. The exception to this was the age variable which was continuous. Decisions about at which values the variables should be treated thus were based on an inspection of the distribution of values on the raw values of the variables, along with what made sense from a conceptual point of view (e.g., any employment ('FT, PT, or casual') vs 'none'). In this analysis we have clustered standard errors by country. The variables entered into the logistic regression equations (see Table 5) were: Gender, Age (continuous), Employment (Y/N), Urbanicity (trichotomized), Education (trichotomized), Selling as a reason to grow (Y/N), Grow area (dichotomized), Number of mature plants typically grow per crop (trichotomized), Total crops grown (trichotomized), Mainly grow outdoors

(Y/N), Perceived legality of growing (trichotomized), and Grow method (soil under natural sunlight (S-NL); soil under artificial light (S-AL); non-soil under artificial light (NS-AL) and non-soil under natural light (NS-NL). The listwise deletion of cases produced an analytic sample for the logistic regression analysis of *N*=4180.

Results

Demographic characteristics

Table 1 presents the demographic characteristics by country of the whole sample (N =11,479). Due to the large sample size there were significant country by country differences on all variables. While the sample was predominantly male (85.8%) there was a noticeably lower proportion of males in New Zealand (60.9%). Furthermore, though the overall median age was 37 (range 18-80) it varied from a high of 53 in the US to a low of 24 in Italy.

Growing method and scale

Table 2 presents the results of the growing method and scale questions which were also asked for the whole sample (N=11,479). Again, while there were differences between countries, those make sense from a climate and growing opportunity perspective, as shown in Supplementary Table S1. Overall, 40.5% of the sample said they exclusively grew indoors. Some 80.4% of respondents grew their plants in living organic soil as opposed to in water (hydroponics) (6.3%) or other grow media. While 56.4% reported only using organic additives, 8.7% of respondents reported only using chemical fertilizers, supplements, and insecticides, with 17.9% using both chemical and organic additives. Most respondents (80.6%) reported they grew no more than 6 mature plants per crop, 8.7% grew 7-10 mature plants and 10.7% more than 10. Over half (55.9%) reported growing in an area of not more than 3squ metres. Only 7.1% of respondents said that selling was one of the reasons they grew.

Results from the Optional Growing Methods Module

Data from the optional growing method and scale questions which were asked of respondents in 10 countries is presented in Tables 3-5 and by country in Supplementary Tables S1-S3. Table 3 presents growing methods, lighting and other equipment used. Growing in soil and artificial light (S-AL) was the most popular typical method (57.6%), followed by soil and sunlight (S-NL) (23.6%) reported by more respondents than the hydroponic method (NS-AL) (17.4%). Interestingly, when asked to identify what kinds of lighting they typically used, more respondents identified LED lamps (57.3%) than sunlight (51.3%) in this multiple response variable. Overall respondents who used artificial lighting reported that they used a median total wattage of 400 Watts (IQR 200-700 Watts). The list of other equipment used by respondents was vast, with Timer unit (63.6%), Oscillating fan (56.7%) and Grow tent (56.3%) used by over half the respondents to this module. Typical grow location is presented in Table 4. Growing outside on one's own property was identified by a just over third (34.3%) of respondents, closely followed by growing in a house/apartment room used for other things (29.7%).

Variables associated with chemical use

Bivariate comparisons of variables associated with the use of chemical fertilizers, supplements, and insecticides are, presented in Table 5. to examine the factors related to use of these chemicals. This suggests that there were differences according to the gender ($\chi2 = 11.47$, df=2, $p = .003$), age ($t = -6.173$, df=4178, $p < .001$), education level ($\chi2 = 21.83$, df=2, $p < .001$) and urbanicity ($\chi2 = 33.87$, df=2, $p < .001$) of the respondent, whether they grew for environmental reasons ($\chi2 = 33.49$, df=1, $p < .001$), whether selling was a reason to grow ($\chi2 = 19.58$, df=1, $p < .001$), the total grow area ($\chi2 = 4.77$, df=1, $p = .029$), the typical number of lifetime grows ($\chi2 = 14.78$, df=2, $p = 0.001$), the grow method used ($\chi2 = 618.43$, df=3, $p < .001$), whether they mainly grew outside ($\chi2 = 98.07$, df=1, $p < .001$) and the perceived legality of cannabis growing where they grew ($\chi2 = 55.50$, df=2, $p < .001$). With regards to grow method used, although the proportion of NS-AL (hydroponic) growers who were using chemicals was greater (65.4%) than those who were growing in S-AL (25.5%), the greater number of soil growers meant the numbers of chemical users in that category (n=629) was greater than the chemical users in the hydro group (n=508).

The binomial logistic regression analysis presented in Table 6 showed that when controlling for the effect of all these other variables and clustering by country, the use of chemical fertilizers, nutrients and supplements was predicted by gender, age, urbanicity, growing for environmental reasons, selling as a reason to grow, grow method, and the perceived legality of cannabis where they grew. Specifically, controlling for all other predictors: males had 1.50 times greater odds than females of using chemicals; for each additional year of age respondents had 1.01 times greater odds of using chemicals; compared to urban/city dwellers, those in suburban areas were at 16% smaller odds, and those in rural areas were at 30% smaller odds, of reporting use of chemicals. Those who grew for environmental reasons were at 30% smaller odds of reporting chemical use; and those who said that selling was a reason to grow were 1.64 times greater odds of reporting chemical use than those who did not. Those that said they grew in S-AL were at 2.18 times greater odds of using chemical fertilizers than those who grew in S-NL; and those who grew using hydroponic methods (NS-AL) were at 11.20 times greater odds of using chemical fertilizers than those who grew in S-NL. Those who grew in a legal environment where any adult use (both medical and recreational) was legal, were 1.74 times greater odds of reporting use of chemicals than those in a full prohibition environment. None of the other predictors in the final model reached significance.

Comparisons between countries and survey years in self-reported chemical use

Figure 1 presents the proportion of respondents who responded that they used any chemical fertilizers, supplements, or insecticides, for both the 18 countries in the current sample and the four countries that reported on this question in the optional module in the 2012-13 data collection. While there are obvious country by country differences, what is noteworthy is the significant reduction in the proportion of growers reporting use of these chemicals in the three countries for whom we have data for both years. Using non-parametric statistics, the overall by year difference was significant ($\chi 2 = 10.470$, df=2, $p < .005$) and for each of these countries by year as well (Australia: $\chi 2 = 54.577$, df=1, $p < .001$; Denmark: $\chi 2 = 9.628$, df=1, $p = .002$; GBR: $\chi 2 = 103.623$, df=1, $p < .001$).

Discussion

Grow method and scale

We successfully surveyed a large international sample of predominately small-scale growers, with 4 in 5 of the sample growing not more than 6 mature plants per crop. As in 2012-13 (Lenton, et al., 2018), we again found that roughly 4 in 5 respondents grew their plants in organic soil, and for almost 6 in 10 of the sample who completed the optional grow methods module cannabis growing was done in soil under artificial light (S-AL), higher than the less than 5 in 10 we found in the three countries we asked the question of in 2012-13 (Lenton, et al., 2018). For climatic reasons, lack of access to an outdoor growing space, growing control, and avoiding detection, it is unsurprising that much of the soil growing is done indoors under artificial light. Although we have again found, as we did in 2012-13 (Lenton, et al., 2018) that growing by the hydroponic (NS-AL) method was used by less than 1 in 5 growers in our samples.

As we found in 2012-13 (Lenton, et al., 2018), and as previously noted by Decorte (2010), the use of 'sophisticated' growing techniques and equipment was common in our sample. For example, over 6 in 10 of those who completed the grow methods module used timer units, more than half reported use of grow tents and oscillating fans, and almost half used thermometers, extractor fans, carbon filters and pH test kits. This suggests, again, that having growing equipment in place should not be taken as indication of a professional, commercial, or organized crime type of growing operation (Decorte, 2010; Lenton, et al., 2018; Potter & Klein, 2020) In Italy, for instance, the use of rudimentary/non-sophisticated techniques is necessary to avoid criminal sanctions for cultivating cannabis (Fiorentini, 2019). Particularly with the growth of online sources providing advice and instructions in such things, increasingly what has been viewed as 'sophisticated' equipment by law enforcement and others, is common for your average, small-time cannabis grower in this sample. Furthermore, developments in lighting, such as low-voltage full-spectrum (like sunlight) LEDs, now available from most hardware stores and residential lighting shops, means that growers don't have to use high voltage and heat producing light sources such as high-pressure sodium and metal halide lamps which were previously more common in our 2012-13 sample. Presumably, this has benefits for the safety of indoor grows as well as the power load and heat signature that was previously reported to be used by law enforcement in some countries to detect grow houses (Potter & Chatwin, 2012; Potter & Klein, 2020)

Predictors of chemical use

As we found in the earlier study (Lenton, et al., 2018), growers using hydroponic methods (NS-AL) were the most likely to use chemical fertilizers, but while soil and artificial light growers (S-AL) were close to 5 times less likely than the hydro group to use chemicals, their larger weight of numbers meant there were more chemical users in the S-AL group than the NS-AL group, and overall they comprised over half of all the chemical users in the sample. This suggests that efforts at informing and educating cannabis growers about the problems of chemical fertilizer, nutrient and pesticide use should not underestimate the importance of reaching growers who grow in soil under artificial light. Whereas in the 2012-13 study, the only significant multivariate predictors of chemical use was grow method, (NS-AL and S-AL) (Lenton, et al., 2018), in the current study we found that gender, age, urbanicity, growing for environmental reasons, selling as a reason to grow, grow method, and the perceived legality of cannabis where they grew, remained significant in the multivariate model. Some of these results reflect the addition of new questions in the questionnaire and a different pool of questions being added in the model, which is relevant for urbanicity, growing for environmental reasons, and the perceived legality of cannabis where they grew. However, selling as a reason to grow only managed to remain significant in the final model in the current study. Whether this reflects genuine changes, or simply a larger sample resulting in this remaining significant in the final model remains unclear. The findings with regards to growing methods remain the strongest and have been addressed above. The findings that those who grew to sell, and male growers, were significant independent predictors of chemical use makes sense on face value. Similarly, the fact that urban/city dwellers, versus those in suburban and rural areas, were more likely to use chemicals, separate to the grow method, could be due to a number of factors. These could include size of grow, not having access to an outdoor growing environment, maybe potentially higher levels of scrutiny/visibility by law enforcement and others in urban/city locations which may dispose someone toward more intensive and concealed crops, or potentially accessibility of grow shops selling chemical fertilizers. Clearly, more research is required to understand this finding.

Importantly, the finding that chemical use was more common among those that said they grew in an environment where medical or recreational growing was legal, compared to prohibited, was possibly unexpected by many on the assumption that legal environments are, by definition, more regulated and produce 'safer' products. However, as has previously been shown, in profit-driven commercially-oriented legal markets the desire of industry to make profit and avoid additional costs can override public health concerns (Lenton, 2020; Subritzky, Lenton, & Pettigrew, 2016; Subritzky, Pettigrew, & Lenton, 2016; Subritzky, et al., 2017). It is thus, perhaps unsurprising that the odds of chemical use were somewhat greater in environments where growing cannabis for medical reasons is legal and were even greater where growing for recreational use was also legal. We have seen in environments where cannabis use for medical and /or recreational reasons is legal, particularly those in North America, that there is a proliferation of all aspects of business associated with the drug, including outlets, advertising and promotion, cannabis industry employment, etc (Fischer, Daldegan-Bueno, & Boden, 2020; Subritzky, Lenton, & Pettigrew, 2016; Subritzky, Pettigrew, & Lenton, 2016). It is to be expected that in such environments the promotion and sale of cannabis specific growing products containing 'nutrients' and chemicals could perhaps be more common and normalized than in prohibited markets where such products are less available and less promoted. Whatever the case, this result suggests that jurisdictions contemplating legalization of medical or recreational cannabis cultivation should ensure they effectively regulate the cannabis nutrient and fertilizer industry, and inform people who grow and use cannabis about the risks of inappropriate or toxic chemical fertilizers on cannabis. As we have said above, regulation is made more challenging in markets where there is a considerable proportion of online sales and international importation..

Notwithstanding the findings of this multivariate analysis which identifies predictors of chemical fertilizer use, it is important to say that regulatory and educational efforts to inform growers about the problems of chemical fertilizer, nutrient and pesticide use should not be limited to those groups identified as more likely to use chemicals in this analysis. Furthermore, whether cannabis cultivation is legal or illegal, it is not enough to have cannabis nutrient and fertilizer product regulations 'on the books' — they need to be clear, enforceable and enforced.

Apparent decreases in use of chemicals

We did find significant reductions in the proportions of our samples who reported using chemical fertilizers from 2012 to 2020 in those three countries where we collected data in both waves (Australia, Denmark, and the UK). The caveat here is that these two data collections comprise different cross-sectional samples, rather than a longitudinal or repeated measures studies. It is unclear the extent to which the observed differences reflect methodological factors, such as, sample differences or the effect of social desirability on responses with people less likely to admit they use chemical fertilizers. Alternatively, the reported reduction in the use of chemicals could reflect more fundamental changes. These could include increased recognition among growers of problems associated with chemical fertilizer use as a result of their own research, advocacy by others including vendors selling fertilizers and nutrients, or demands for more healthy cannabis by cannabis consumers. Other factors such as the narrowing price differential and/or yield gap between organic and chemical products for horticulture (Brzozowski & Mazourek, 2018; Ponisio, et al., 2015), or the development of cultivars which are adapted to be treated without chemical products, could also be relevant.

In an anonymous online survey where IP addresses are not collected, one would think that factors such as social desirability would be less of a factor than in face-to-face research methods. Additionally, in recent years, we have seen user advocacy regarding the problems of PGRs in cannabis and how to recognize PGR affected cannabis in many countries building on that which was done earlier (Hermes, 2011; Manic Botanix, undated; Sirius, 2016) in North America. For example, in Australia there have been extensive efforts by cannabis advocates (Lagrasso, 2021; Lu, 2022) to inform and educate people who use and/or grow cannabis about the dangers of PGRs and how to identify cannabis that has been grown with them. In New Zealand there have been high profile drug alerts sent out to the drug using community regarding the issues (Drug Information and Alerts Aotearoa New Zealand (DIANZ), 2021). Cannabis advocates targeting German speaking countries have also been addressing PGRs (Weedhack Staff writer, 2023), as have medical cannabis prescribers in the USA (e.g. Dugar, 2022) and the cannabis press in the UK (Ledger, 2022). A number of commercial entities, such as one seed company from the Netherlands (Dutch Passion, 2023) and one based in Spain (Stumper, 2022), also have been providing information about PGRs. Further, some activists have reported witnessing a sea-change in consciousness about these issues among people who use and/or grow cannabis in recent years (e.g. Lagrasso, 2021). It is thus possible that our findings reflect a true reduction in the use of chemicals, which may be related to the advocacy/activism within the cannabis using and growing community, and potentially some retailers of cannabis targeted fertilizers and nutrients changing their advice and product offerings in response to grower demands.

Limitations

As we have previously noted (Lenton, et al., 2018) the primary limitation of this methodology is that it is a self-selected non-representative sample, and thus, cannot be used to draw conclusions about the broader population of cannabis cultivators.

Yet because cannabis growers often comprise a very small proportion of representative general population samples (Barratt & Lenton, 2015) and are a hidden and stigmatized population, we believe purposive sampling provides a valid and cost-effective means to explore this under-researched group. We also concede the potential criticism that we are not likely to get at large scale illegal growers who are such an important part of the market. However, we note that much of the previous research on cannabis growers has been done on law enforcement data which often includes these larger-scale growers and make the point that our primary target, even in a changing world with larger scale legal commercial growers in some countries, was the smaller scale growers. We also note the concern regarding multiple responders in web surveys of this sort, but this is more likely where there is some financial or other re-imbursement for participation, which we did not employ in this nor in our previous survey (Barratt, et al., 2015). It was again gratifying that when we applied the appropriate statistical tools to identify such cases that these were very small in number and, whilst we removed them from the final sample, most seemed to be a function of initial non-completers logging in again to complete the survey rather than apparent deliberate attempts to be double counted. As we noted above, for practical reasons, we did not ask growers to identify the brands of fertilizers which they used. We acknowledge that this is an important limitation of our work as we are not able to definitively say whether those respondents using chemical nutrients and fertilizers were using products containing PGRs, pesticides and other compounds which have been shown to be harmful to health. However, as we have noted, the presence of PGRs and other toxic chemicals in growing cannabis nutrients and fertilizers and being found in cannabis in the market continues to be an issue in many countries (Drug Information and Alerts Aotearoa New Zealand (DIANZ), 2021; Dugar, 2022; Dutch Passion, 2023; Lagrasso, 2021; Ledger, 2022; Lu, 2022; Stumper, 2022; Weedhack Staff writer, 2023). Furthermore, the way the question was asked, as explained in the Methods, does mean that it is in the 'chemicals' group where potentially harmful nutrients, fertilizers and pesticides will be found. Consequently, while the findings are not definitive regarding *risky* chemical use, they do point to which growers could be targeted with interventions to raise the issue to reduce risk. Beyond this, in our future work we will continue to explore how we can usefully get more information on which products growers are using and with, better data on product contents, be able to draw stronger conclusions on the use of noxious chemicals.

Future research

It is encouraging to see the growth of recognition of the problems of synthetic PGRs in the cannabis using and growing community and the efforts from a number of advocacy and commercial entities to inform and educate growers and discuss the issue in various fora. However, we still have a significant international industry which is producing nutrient and fertilizer products for cannabis growers which remains ineffectively regulated with little-to-no enforcement of accuracy and transparency in product labelling. Many of these products have labels that misrepresent their true contents and contain chemicals that increase yield, but are toxic, and get into the cannabis which is consumed. One of the leading reasons why people who use cannabis choose to grow their own cannabis is to have control of the growing process and the product quality (Potter, et al., 2015), but if they cannot be certain of what is in the products that they use to grow their cannabis, they cannot reduce the toxic effects. This also means many people who are cultivating cannabis medicinally for sick family and friends with the belief they are helping (Hakkarainen, et al., 2015; Klein & Potter, 2018) may be harming them. We believe that future research should be done in two areas: Firstly, toxicological studies of the fertilizers and nutrients marketed to cannabis growers, and secondly, qualitative studies with cannabis growers which focuses on their use of nutrients and fertilizers. The former could involve (i) Purchasing a range of nutrient and fertilizer products targeted at people who grow cannabis, (ii) Chemical analysis of those products using state-of-the art liquid chromatography mass spectrometry (LC-MS) to identify PGRs and other potentially toxic chemicals in these products, and (iii) Compare those contents to the descriptions of product contents on product labels, websites and associated documents. The qualitative research could comprise interviews with cannabis growers with a particular focus on their practices of using chemicals/nutrients/fertilizers, to explore their motives for using these products, their knowledge about these products, their main supply channels for acquiring these products, their awareness of the risks involved, and their beliefs regarding these growing practices. In our view such toxicological and qualitative research is needed to complement and inform the growing community advocacy on this important harm reduction topic. Cannabis growers have a right to know what chemicals are in the products that are marketed and sold to enhance their crops whether they operate in legal or illegal, cannabis markets. People who use cannabis have a right to know what harmful additives may exist in the cannabis that they buy and consume whether from legal or illegal markets.

Conflict of interest

No conflict declared.

Acknowledgements

We would like to thank the many thousands of cannabis cultivators who have completed our online questionnaires and contributed their knowledge and experience to this work. Our research would not be possible without their efforts. Thanks also to all the people and organizations who supported and promoted our research, and all the *coffeeshops*, grow shops and headshops that helped us. Thanks to all our colleagues from the GCCRC who contributed to the design, conduct and analysis of the questionnaire. An earlier version of this paper was presented at the International Society for the Study of Drug Policy Conference in Leuven, Belgium, in 2023.

Supplementary Tables

Supplementary tables referred to in this article can be found at: [Web archive for IJDP]

Table 1: Demographic characteristics by country

	AUS	AUT	BEL	CAN	CHE	DEN	DEU	FIN	FRA	TOTAL	Sig.
Gender %	(n=723)	(n=44)	(n=2,084)	(n=513)	(n=277)	(n=873)	(n=787)	(n=524)	(n=681)	(N=11,308)	<.001
Male	82.0%	79.5%	89.6%	83.4%	88.4%	80.6%	92.0%	88.9%	92.1%	85.8%	
Female	17.6%	13.6%	10.0%	15.4%	10.1%	18.7%	7.2%	10.1%	6.8%	13.3	
Non-binary	0.4%	6.8%	0.3%	1.2%	1.4%	0.7%	0.8%	1.0%	1.2%	0.8	
Age in yrs.	(n=732)	(n=44)	(n=2,107)	(n=519)	(n=282)	(n=883)	(n=801)	(n=536)	(n=690)	(N=11,479)	<.001
Median	46	34	33	41	37	40	33	36	36	37	
Mean	45.6	36.5	34.3	42.5	39	41.9	34.4	37.2	38	39.1	
IQR	35-56	26-47	25-41	33-51	29-49	29-53	25-41	29-44	29-45	27-49	
Range	18-80	18-71	18-80	18-77	18-74	18-80	18-77	18-70	18-75	18-80	
Currently Studying %	(n=638)	(n=43)	(n=1,899)	(n=475)	(n=247)	(n=787)	(n=725)	(n=500)	(n=616)	(N=10,217)	<.001
Full Time	4.4%	11.6%	16.0%	5.9%	7.3%	12.2%	13.1%	12.8%	8.0%	12.0%	
Part time	12.2%	9.3%	8.7%	8.2%	9.7%	2.7%	4.1%	9.0%	5.2%	9.5%	
Not studying	83.4%	79.1%	75.3%	85.9%	83.0%	85.1%	82.8%	78.2%	86.9%	78.4%	
Currently employed %	(n=638)	(n=42)	(n=1,884)	(n=477)	(n=251)	(n=790)	(n=736)	(n=496)	(n=610)	(N=10,211)	<.001
Yes	52.5%	69.0%	69.0%	66.9%	69.3%	53.3%	68.1%	47.6%	62.5%	58.2%	

	GBR	GEO	ISR	ITA	NLD	NZL	PRT	URY	USA	TOTAL	
Gender %	(n=340)	(n=215)	(n=87)	(n=1,350)	(n=355)	(n=197)	(n=111)	(n=340)	(n=1,807)	(N=11,308)	<.001
Male	83.2%	94.0%	90.8%	87.5%	85.4%	60.9%	87.4%	77.1%	82.3%	85.8%	
Female	16.5%	5.1%	9.2%	11.5%	13.8%	36.0%	11.7%	21.8%	17.0%	13.4%	
Non-binary	0.3%	0.9%	0.0%	1.0%	0.8%	3.0%	0.9%	1.2%	0.6%	0.8%	
Age in yrs.	(n=341)	(n=218)	(n=87)	(n=1,400)	(n=359)	(n=198)	(n=114)	(n=342)	(n=1,826)	(N=11,479)	<.001
Median	47	29	28	24	42	47	31	28	53	37	
Mean	47.2	30.6	30.2	27.8	42.5	47.4	33.2	30.9	51.7	39.1	
IQR	39-55	24-36	23-35	20-33	31-53	37-57	26-40	22-36	40-63	27-49	
Range	18-80	18-60	18-68	18-69	18-79	20-79	19-70	18-77	18-80	18-80	
Currently Studying %	(n=309)	(n=164)	(n=71)	(n=1,235)	(n=312)	(n=183)	(n=111)	(n=265)	(n=1,637)	(N=10,217)	<.001
Full Time	2.6%	12.8%	18.3%	30.2%	8.0%	4.4%	13.5%	11.3%	3.0%	12.0%	
Part time	8.4%	18.3%	21.1%	13.8%	9.0%	10.4%	16.2%	35.1%	8.4%	9.5%	
Not studying	89.0%	68.9%	60.6%	56.0%	83.0%	85.2%	82.8%	53.6%	88.6%	78.4%	

Currently employed %	(n=310)	(n=165)	(n=69)	(n=1,241)	(n=304)	(n=182)	(n=109)	(n=265)	(n=1,642)	(N=10,211)		<.001
Yes	55.5%	55.2%	58.0%	47.1%	57.9%	50.0%	70.6%	66.8%	50.9%	58.2%		

Table 2: Growing method and scale

Grows indoors or outdoors	n	%
Indoors	4,611	40.5
Indoors and outdoors	2,895	25.4
Outdoors (including greenhouses)	2,288	20.1
Seedlings grown indoors, then planted outdoors	1,600	14.0
Total	11,394	100.0
Usual root medium	n	%
Living organic soil	9,156	80.4
Water (i.e., hydroponic)	715	6.3
Coco coir/coconut	379	3.3
Organic/nonorganic mix	347	3.0
Perlite	329	2.9
Soil and organic mediums	236	2.1
Air (e.g. nutrient mist)	50	0.4
Rock wool	32	0.3
Unspecified mix/substrate	35	0.3
Nonorganic mediums	23	0.2
Varies indoor/outdoor	20	0.2
Multiple/mixed mediums	27	0.2
Other medium	23	0.2
Varies by growth stage	11	0.1
Total	11,383	100.0
Fertilizers, supplements or insecticides typically used	n	%
Organic only	6,360	56.4
Chemical only	976	8.7
Both	2,018	17.9
None	1,920	17.0
Total	11,274	100.0
Growing area (dichotomized)	n	%
up to 3 sqm	5,380	55.9
over 3 sq m	4,246	44.1
Total	9,626	100.0
Mature plants typically grow per crop	n	%
1-6	9,070	80.6
7-10	981	8.7
More than 10	1,200	10.7
Total	11,251	100.0
Selling as a reason I grow	n	%
No	10,641	92.9
Yes	817	7.1
Total	11,458	100.0

Table 3: Grow method, lighting and other equipment used.

Grow method (light source x grow medium)	n	%
soil & artificial light (S-AL)	3,173	57.6
soil & sunlight (S-NL)	1,299	23.6
non-soil & artificial light (NS-AL)	956	17.4
non-soil & sunlight (NS-NL)	81	1.5
Total	5,509	100.0
Lighting source*	n	%
LED lamps	3,166	57.3
Sunlight	2,837	51.3
High pressure sodium lamps	1,056	19.1
Metal halide lamps	525	9.5
Fluorescent lamps	514	9.3
Energy saving lamps	208	3.8
UV lamps	203	3.7
LEC lamps	5	0.1
Other	15	0.3
Total N	5,529	
Other Equipment & materials*	n	%
Timer unit	3,354	63.6
Oscillating fan	2,993	56.7
Grow tent	2,969	56.3
Thermometer	2,569	48.7
Extractor fan	2,518	47.7
Carbon filter	2,514	47.7
PH test kit	2,501	47.4
Light reflective wall lining	2,269	43.0
Growing substrates	2,130	40.4
Exhaust system	1,697	32.2
Inlet fan	1,655	31.4
Water pump	762	14.4
Air pump	678	12.9
Fan silencer/dampener	628	11.9
Water heater	211	4.0
Humidifier	72	1.4
Dehumidifier	76	1.4
monitors/controllers	69	1.3
EC/TDS meter	45	0.9
Hygrometer	35	0.7
Heater	26	0.5
Aircon - cooler	23	0.4
CO2 source	22	0.4
Other	145	2.7
No other equipment/materials	921	17.5
Total N	5,275	

* Multiple responses were possible

Table 4: Typical grow location

Location where typically grow*	n	%
Outdoors, on own property	1,805	34.3
In a house/apartment room used for other things	1,563	29.7
In a basement/cellar	741	14.1
In a house/apartment dedicated grow room	724	13.7
Inside a cupboard/closet	631	12.0
On a balcony	525	10.0
In a greenhouse	470	8.9
Outdoors, on public or state-owned land	329	6.2
Inside a shed	309	5.9
Outdoors, on other private property	292	5.5
In an attic/loft	161	3.1
In a warehouse	85	1.6
In a garage	45	0.9
In a grow house	40	0.8
Other	42	0.8
Total N	5,275	

* Multiple responses were possible

Table 5: Variables associated with use of chemicals*

	No Chemicals	Use Chemicals	Total	Sig.
Gender %	(n=2922)	(n=1258)	(n=4180)	.003
Male	69.0%	31.0%	100.0%	
Female	76.4%	23.6%	100.0%	
Non-Binary	68.0%	32.0%	100.0%	
Total	69.9%	30.1%	100.0%	
Urbanicity%	(n=2922)	(n=1258)	(n=4180)	< .001
Urban/City	65.7%	34.3%	100.0%	
Suburban	70.3%	29.7%	100.0%	
Rural	76.0%	24.0%	100.0%	
Total	69.9%	30.1%	100.0%	
Age (yrs)	(n=2922)	(n=1258)	(n=4180)	
Median	40	42	40	
Mean Age	41.3	44.5	42.3	< .001
IQR	28-53	33-56	30-54	
Range	18-80	18-80	18-80	
Education %	(n=2922)	(n=1258)	(n=4180)	< .001
Less than High school	79.3%	20.7%	100.0%	
High school or equivalent	69.2%	30.7%	100.0%	
College or above	68.1%	31.9%	100.0%	
Total	69.9%	30.1%	100.0%	
Employment %	(n=2922)	(n=1258)	(n=4180)	.333
Not employed	72.1%	29.9%	100.0%	
Employed incl. self employed	69.3%	30.7%	100.0%	
Total	71.0%	29.0%	100.0%	
Grows for environmental reasons %	(n=2922)	(n=1258)	(n=4180)	< .001
No	67.7%	32.3%	100.0%	
Yes	77.4%	22.6%	100.0%	
Total	69.9%	30.1%	100.0%	
Grow to Sell %	(n=2922)	(n=1258)	(n=4180)	< .001
No	70.8%	29.2%	100.0%	
Yes	59.1%	40.9%	100.0%	
Total	69.9%	30.1%	100.0%	
Grow area %	(n=2922)	(n=1258)	(n=4180)	.029
Up to $3m^2$	68.6%	31.4%	100.0%	
Over $3m^2$	71.7%	28.3%	100.0%	
Total	69.0%	30.1%	100.0%	

* Due to listwise deletion the N for this table is 4180

Table 5: Variables associated with use of chemicals cont.*

	No Chemicals	Use Chemicals	Total	Sig.
Typical mature plants per crop %	(n=2922)	(n=1258)	(n=4180)	.088
6 or less	70.6%	29.4%	100.0%	
7 to 10	69.8%	30.2%	100.0%	
More than 10	65.8%	34.2%	100.0%	
Total	69.9%	30.1%	100.0%	
Lifetime crops grown %	(n=2922)	(n=1258)	(n=4180)	.001
0 to 2	73.1%	26.9%	100.0%	
3 to 9	71.3%	28.7%	100.0%	
More than 10	66.6%	33.4%	100.0%	
Total	69.9%	30.1%	100.0%	
Grow method %	(n=2922)	(n=1258)	(n=4180)	< .001
Soil & sunlight (S-NL)	87.6%	12.4%	100.0%	
Soil & Artificial light (S-AL)	74.5%	25.5%	100.0%	
Non-soil & Artificial light (NS-AL)	34.6%	65.4%	100.0%	
Non-soil & sunlight (NS-NL)	77.5%	22.5%	100.0%	
Total	71.0%	29.0%	100.0%	
Mainly grows outdoors %	(n=2922)	(n=1258)	(n=4180)	< .001
No	62.8%	37.2%	100.0%	
Yes	76.8%	23.2%	100.0%	
Total	69.0%	30.1%	100.0%	
Perceived legality of cannabis growing	(n=2922)	(n=1258)	(n=4180)	< .001
Prohibited	73.0%	27.0%	100.0%	
Medical only legal	70.9%	29.1%	100.0%	
Any adult use legal	59.8%	40.2%	100.0%	
Total	69.0%	30.1%	100.0%	

* Due to listwise deletion the N for this table is 4180

Table 6: Binomial Logistic Regression predicting use of chemical fertilizers, supplements and insecticides (N=4180)

Use of Chemicals	OR	95% CI	Sig.
Gender			
Female	1		
Male	1.496	1.262-1.773	< .001
Non-Binary	1.703	0.477-2.886	.241
Age (yrs)	1.011	1.002-1.019	.011
Employed			
No	1		
Yes	1.084	0.884-1.328	.439
Urbanicity			
Urban/City	1		
Suburban	0.842	0.738-0.960	.010
Rural	0.704	0.572-0.866	.001
Highest education level achieved			
Primary school only	1		
High school or equivalent	1.303	0.933-1.820	.120
University/college	1.397	0.970-2.011	.073
Grows for environmental reasons			
No	1		
Yes	0.692	0.604-0.793	< .001
Grow to Sell			
No	1		
Yes	1.637	1.271-2.109	< .001
Grow area			
Up to 3m^2	1		
Over 3m^2	0.993	0.866-1.138	.921
No. mature plants typically grow			
0-6	1		
7-10	1.042	0.839-1.292	.710
More than 10	0.965	0.759-1.228	.773
Lifetime number crops grown			
1-2	1		
3-9	0.906	0.669-1.227	.523
10 or more	0.894	0.664-1.203	.461
Grow method			
Soil & sunlight (S-NL)	1		
Soil & Artificial light (S-AL)	2.178	1.618-2.932	< .001
Non-soil & Artificial light (NS-AL)	11.205	8.382-14.980	< .001
Non-soil & sunlight (NS-NL)	2.180	0.616-7.716	.227
Grow outside			
No	1		
Yes	0.847	0.700-1.024	.087
Perceived legality of cannabis growing			
Prohibited	1		

Medical only legal	1.129	0.827-1.541	.444
Any adult use legal	1.745	1.041-2.926	.035
Constant	0.610	0.040-0.092	<.001

N.B. This analysis was clustered by Country.

Figure 1: Country by year by any chemical fertilizer use

References

Atapattu, S. N., & Johnson, K. R. D. (2020). Pesticide analysis in cannabis products. *Journal of Chromatography A, 1612*. 460656. DOI: 10.1016/j.chroma.2019.460656.

Barratt, M. J., Bouchard, M., Decorte, T., Vibeke Asmussen, F., Hakkarainen, P., Lenton, S., Malm, A., Nguyen, H., & Potter, G. R. (2012). Understanding global patterns of domestic cannabis cultivation. *Drugs and Alcohol Today, 12*,4. 213-221.

Barratt, M. J., & Lenton, S. (2015). Representativeness of online purposive sampling with Australian cannabis cultivators. *International Journal of Drug Policy, 26*,3. 323-326. DOI: http://dx.doi.org/10.1016/j.drugpo.2014.10.007.

Barratt, M. J., Potter, G. R., Wouters, M., Wilkins, C., Werse, B., Perälä, J., Pedersen, M. M., Nguyen, H., Malm, A., Lenton, S., Korf, D., Klein, A., Heyde, J., Hakkarainen, P., Frank, V. A., Decorte, T., Bouchard, M., & Blok, T. (2015). Lessons from conducting trans-national Internet-mediated participatory research with hidden populations of cannabis cultivators. *International Journal of Drug Policy, 26*,3. 238-249. DOI: http://dx.doi.org/10.1016/j.drugpo.2014.12.004.

Bengyella, L., Kuddus, M., Mukherjee, P., Fonmboh, D. J., & Kaminski, J. E. (2022). Global impact of trace non-essential heavy metal contaminants in industrial cannabis bioeconomy. *Toxin Reviews, 14*,4. 1215-1225. DOI: 10.1080/15569543.2021.1992444.

Brzozowski, L., & Mazourek, M. (2018). A sustainable agricultural future relies on the transition to organic agroecological pest management. *Sustainability (Switzerland), 10*,6. DOI: 10.3390/su10062023.

Decorte, T. (2010). Small scale domestic cannabis cultivation: An anonymous Web survey among 659 cannabis cultivators in Belgium. *Contemporary Drug Problems, 37*,2. 341-370.

Decorte, T., Lenton, S., & Wilkins, C. (2020). Legalizing Cannabis: Experiences, Lessons and Scenarios. In (1st ed., pp. 484). London: Routledge.

Decorte, T., & Potter, G. R. (2015). The globalisation of cannabis cultivation: A growing challenge. *International Journal of Drug Policy, 26*,3. 221-225. DOI: http://dx.doi.org/10.1016/j.drugpo.2014.12.011.

Drug Information and Alerts Aotearoa New Zealand (DIANZ). (2021). *High Alert: What is PGR cannabis and how do you spot it?* Available at: https://highalert.org.nz/articles/what-is-pgr-cannabis-and-how-do-you-spot-it/ [Accessed 13.06.23].

Dugar, A. (2022). *The Problems of PGR Weed & How to Spot Them*. Available at: https://greenhealthdocs.com/pgr-weed/#:~:text=The%20three%20most%20common%20synthetic,densest%20part%20of%20the%20plant. [Accessed 13.06.23]: Green Health Docs.

Dutch Passion. (2023). *Should you consider cannabis grown with PGR?* Available at: https://dutch-passion.com/de/blog/sollte-man-mit-pgr-angebautes-cannabis-in-betracht-ziehen-n1130 [Accesseed 13.06.23]: Dutch Passion.

Fiorentini, L. (2019). *Italy: Supreme Court rule on cannabis cultivation and the shame of politicians*. Fuoriluogo. Published 31 December 2019. Available at: https://www.fuoriluogo.it/globe/italy-the-decision-of-the-supreme-court-on-cannabis-cultivation-and-the-silence-of-politics/?lang=en [Accessed 08.01.24].

Fischer, B., Daldegan-Bueno, D., & Boden, J. M. (2020). Facing the option for the legalisation of cannabis use and supply in New Zealand: An overview of relevant evidence, concepts and considerations. *Drug and Alcohol Review, 39*,5. 555-567. DOI: 10.1111/dar.13087.

Giancristofaro, R. A., & Salmaso, L. (2003). Model performance analysis and model validation in logistic regression. *Statistica, 63*,2. 375-396.

Global Cannabis Cultivation Research Consortium. (2023). *International Cannabis Cultivation Questionnaire 2.0.* Available from https://worldwideweed.nl (Accessed 21.04.23).

Hakkarainen, P., Frank, V. A., Barratt, M. J., Dahl, H. V., Decorte, T., Karjalainen, K., Lenton, S., Potter, G., & Werse, B. (2015). Growing medicine: Small-scale cannabis cultivation for medical purposes in six different countries. *International Journal of Drug Policy, 26*,3. 250-256. DOI: http://dx.doi.org/10.1016/j.drugpo.2014.07.005.

Health Canada. (2017). *Clarification from Health Canada on myclobutanil and cannabis*: Health Canada. Available at; https://www.canada.ca/en/health-canada/news/2017/03/clarification_fromhealthcanadaonmyclobutanilandcannabis.html (Accessed 5.11.20).

Hermes, K. (2011). *Long-banned Alar (Daminozide) Shows Up on Hydroponic Store Shelves Before Being Removed Again*: Americans For Safe Access. Available at: http://www.safeaccessnow.org/long_banned_alar_daminozide_shows_up_on_hydroponic_store_shelves_before_being_removed_again (Accessed 13.06.16). (Archived by Webcite® at http://www.webcitation.org/6tHzkaNjf).

Integral Hydroponics. (2015). *The Curious Case of the Flower Dragon*. Available at: http://www.integralhydro.com/flower-dragon Accessed 06.07.16) Archived by WWebCite® at http://www.webcitation.org/6tI09rdw5.

Klein, A., & Potter, G. R. (2018). The three betrayals of the medical cannabis growing activist: From multiple victimhood to reconstruction, redemption and activism. *International Journal of Drug Policy, 53*. 65-72. DOI: https://doi.org/10.1016/j.drugpo.2017.12.004.

Lagrasso, J. (2021). *PGR: The Toxic Chemicals in Your Marijuana*. Available at: https://friendlyaussiebuds.com/australian-cannabis-education/pgr-toxic-weed/ [accessed 13.06.23]: Friendly Aussie Buds.

Ledger, E. (2022). *What is PGR weed? And how can you spot it?* Available at: https://www.leafie.co.uk/articles/pgr-weed-spot/ [Accessed 14.06.23]: Leafie.

Lenton, S. (2020). Regulating cannabis retail for public health over private profit. *Addiction* in press.

Lenton, S., Frank, V. A., Barratt, M. J., Potter, G. R., & Decorte, T. (2018). Growing practices and the use of potentially harmful chemical additives among a sample of small-scale cannabis growers in three countries. *Drug and Alcohol Dependence, 192*. 250-256. DOI: 10.1016/j.drugalcdep.2018.07.040.

Lenton, S., Grigg, J., Barratt, M. J., Kowalski, M., Decorte, T., Pardal, M., Martin-Milot, D., Bertrand, K., Bear, D., Asmussen-Frank, V., Friss Soegaard, T., Hakkarainen, P., Jauffret-Roustide, M., Kirtadeze, I., Werse, B., Kamphausen, G., Sznitman, S., Sotto, B., Fortin, D., Wilkins, C., Quintas Oliveira, J., Faria, R., Zobel, F., Granville, A., Potter, G., Malm, A., Sevigny, E. L., Meisel, J., Queirolo, R., Alvarez, E., & Sotto, B. (2023). *An investigation of global patterns of small-scale domestic cannabis cultivation.* Available at: osf.io/kqghe/ [accessed 09.01.24].

Li, J., Sun, L., Zuo, Z., Chen, M., Geng, H., & Wang, C. (2012). Exposure to paclobutrazol disrupts spermatogenesis in male Sebastiscus marmoratus. *Aquatic Toxicology, 122-123*. 120-124. DOI: https://doi.org/10.1016/j.aquatox.2012.06.007.

Long, J. S., & Freese, J. (2014). *Regression models for categorical dependent variables using Stata (3rd ed.)*. College Station: Stata Press.

Lu, J. (2022). *PGR cannabis: what is a plant growth regulator?* Available at: https://budherd.com.au/articles/pgr-cannabis-what-is-a-plant-growth-regulator {Accessed 13.06.23]: Bud Herd.

Manic Botanix. (undated). PGRS and Medical Marijuana. In *Manic Botanix online grow mag. Available at: https://manicbotanix.com/pgrs-and-medical-marijuana/ (Accessed 21.04.17) Archived by WWebCite® at http://www.webcitation.org/6tI1foeUf*. Available at: https://manicbotanix.com/pgrs-and-medical-marijuana/ (Accessed 21/4/17) Archived by WWebCite® at http://www.webcitation.org/6tI1foeUf.

Massachusetts Department of Agricultural Resources. (2012). *Paclobutrazol. Review Conducted by MDAR and MassDEP for Use in Sensitive Areas of Rights-of-Way in Massachusetts*. Available at: https://www.mass.gov/files/documents/2016/08/sl/paclobutrazol-review-jan-2012.pdf (Accessed 15.02.22): MDAR.

McPartland, J. M., & Pruitt, P. L. (1997). Medical marijuana and its use by the immunocompromised. *Alternative Therapies in Health and Medicine, 3*,3. 39-45.

Migoya, D. (2017). State recalls 50 Tree of Wellness medical pot products because of pesticide. *The Denver Post. Available at: https://www.denverpost.com/2017/11/03/tree-of-wellness-medical-pot-product-recall/ (Accessed 14.01.21). Archived by Perma.cc at: https://perma.cc/6JCU-696C.*

Montoya, Z., Conroy, M., Vanden Heuvel, B. D., Pauli, C. S., & Park, S. H. (2020). Cannabis Contaminants Limit Pharmacological Use of Cannabidiol. *Frontiers in Pharmacology, 11*. DOI: 10.3389/fphar.2020.571832.

National Center for Biotechnology Information. (2022). *PubChem Compound Summary for CID 15331, Daminozide.* Retrieved February 15, 2022 from https://pubchem.ncbi.nlm.nih.gov/compound/Daminozide.: NIH National Library of Medicine National Center for Biotechnology Information.

Ponisio, L. C., M'gonigle, L. K., Mace, K. C., Palomino, J., Valpine, P. D., & Kremen, C. (2015). Diversification practices reduce organic to conventional yield gap. *Proceedings of the Royal Society B: Biological Sciences, 282*,1799. DOI: 10.1098/rspb.2014.1396.

Potter, G., Barratt, M. J., Malm, A., Bouchard, M., Blok, T., Christensen, A.-S., Decorte, T., Frank, V. A., Hakkarainen, P., Klein, A., Lenton, S., Perälä, J., Werse, B., & Wouters, M. (2015). Global patterns of domestic cannabis cultivation: Sample characteristics and patterns of growing across eleven countries. *International Journal of Drug Policy, 26*,3. 226-237. DOI: http://dx.doi.org/10.1016/j.drugpo.2014.12.007.

Potter, G., & Chatwin, C. (2012). The problem with "skunk". *Drugs and Alcohol Today, 12*,4. 232-240.

Potter, G., & Klein, A. (2020). Coming out of the closet: risk management strategies of illegal cannabis growers. In S. M. a. B. Thom (Ed.), *Risk and Substance Use: Framing dangerous people and dangerous places* (pp. 201-221). London: Routledge.

Robertson, G. (2017). More than $1million of tainted medical marijuana destroyed. In *the Globe and Mail. Available at: http://www.theglobeandmail.com/news/national/morethan1millionoftaintedmedicalmarijuanadestroyed/article34026223/ (Accessed 19.04.17) [Not able to be archived due to no-cache tag]*

Singh, S. (2023). Global Cannabis Plant Nutrients Market Overview. In *Market Research Future*. Available at: https://www.marketresearchfuture.com/reports/cannabis-plant-nutrients-market-10963 [Accessed 03.11.23].

Sirius, J. (2016). What are PGR'S and why are they in my weed? In *High Times. Available at: http://hightimes.com/grow/what-are-pgrs-and-why-are-they-in-my-weed/ (Accessed 04.01.17). Archived by WWebCite® at http://www.webcitation.org/6iSayqwwH.*

Stumper, L. (2022). *What Are PGRs, and How Do They Affect Your Weed?* Available at: https://www.royalqueenseeds.com/uk/blog-what-are-pgrs-and-how-do-they-affect-your-weed-n1417 [Accessed 13.06.23]: Royal Queen Seeds.

Subritzky, T., Lenton, S., & Pettigrew, S. (2016). Legal cannabis industry adopting strategies of the tobacco industry. *Drug and Alcohol Review, 35*,5. 511-513.

Subritzky, T., Pettigrew, S., & Lenton, S. (2016). Issues in the implementation and evolution of the commercial recreational marijuana market in Colorado. *International Journal of Drug Policy, 27*. 1-12. DOI: http://dx.doi.org/10.1016/j.drugpo.2015.12.001.

Subritzky, T., Pettigrew, S., & Lenton, S. (2017). Into the void: Regulating pesticide use in Colorado's commercial cannabis markets. *International Journal of Drug Policy, 42*. 86-96. DOI: http://doi.org/10.1016/j.drugpo.2017.01.014.

Sullivan, N., Elzinga, S., & Raber, J. C. (2013). Determination of pesticide residues in cannabis smoke. *Journal of Toxicology, 2013*. DOI: 10.1155/2013/378168.

Sytar, O., Ghosh, S., Malinska, H., Zivcak, M., & Brestic, M. (2021). Physiological and molecular mechanisms of metal accumulation in hyperaccumulator plants. *Physiologia Plantarum, 173*,1. 148-166. DOI: https://doi.org/10.1111/ppl.13285.

Taylor, A., & Birkett, J. W. (2020). Pesticides in cannabis: A review of analytical and toxicological considerations. *Drug Testing and Analysis, 12*,2. 180-190. DOI: 10.1002/dta.2747.

UNODC. (2021). *World Drug Report 2021 (United Nations publication, Sales No. E.21.XI.8).* Vienna: United Nations Office on Drugs and Crime.

UNODC. (2023). *Online World Drug Report 2023 - Latest data and trend analysis*: UNODC. Available at https://www.unodc.org/unodc/en/data-and-analysis/wdr-2023-online-segment.html (Accessed 14.07.23).

Venhuis, B. J., & van de Nobelen, S. (2015). *Cannabis contaminants*. Bilthoven. : Rijksinstituut voor Volksgezondheid en Milieu. Available at: https://www.eerstekamer.nl/overig/20160120/rivm_rapport_cannabis/document (accessed 20.06.17).

Voelker, R., & Holmes., M. (2015). *Pesticide use on cannabis*. Available at: https://cdn.technologynetworks.com/tn/Resources/pdf/pesticide-use-on-cannabis.pdf (Accessed 16.11.20): Cannabis Safety Institute.

Weedhack Staff writer. (2023). *The dangers of PGR cannabis & how to identify it*. Available at: https://weedhack.de/pgr-cannabis-duenger-gefahren-identifizieren/ [Accessed 13.06.23]: Weedhack.

Xu, M., & Yang, F. (2020). Integrated gender-related effects of profenofos and paclobutrazol on neurotransmitters in mouse. *Ecotoxicology and Environmental Safety, 190*. DOI: 10.1016/j.ecoenv.2019.110085.

Growing practices and the use of potentially harmful chemical additives from a web survey of mainly small-scale cannabis growers in 18 countries

SIMON LENTON[1], Gary Potter[2], Davide Fortin[3], Ashely Granville[4], Jodie Grigg[1], Eric Sevigny[5], Chris Wilkins[6], Tom Decorte[7] Monica Barratt[8,9]

1. National Drug Research Institute, enAble Institute, Curtin University, Australia
2. Lancaster University Law School, UK
3. Aix Marseille Univ, INSERM, IRD, SESSTIM, Sciences Economiques & Sociales de la Santé & Traitement de l'Information Médicale, ISSPAM, Marseille, France
4. School of Criminal Sciences, University of Lausanne, Switzerland.
5. Department of Criminal Justice and Criminology, Georgia State University, USA.
6. SHORE & Whariki Research Centre, College of Health, Massey University, NZ.
7. Institute for Social Drug Research (ISD), Ghent University, Belgium.
8. Social Equity Research Centre and Digital Ethnography Research Centre, RMIT University, Melbourne, Vic, Australia
9. National Drug and Alcohol Research Centre, UNSW Sydney, NSW, Australia

Growing practices and the use of potentially harmful chemical additives from a web survey of mainly small-scale cannabis growers in 18 countries

Key words: Cannabis cultivation, Marijuana, Policy, Online survey, International comparative research

ABSTRACT

Background: There is emerging recognition of the risks of harmful chemical pesticides, fertilizers and 'nutrients' by cannabis growers. One group of chemicals, Plant Growth Regulators (PGRs), many of which have been banned from food crops for decades, have been found unlisted in a number of fertilizers and supplements marketed at cannabis growers.

Methods: This paper predominately uses data from a 2020-21 convenience web survey of mainly small-scale, recent (last 5yrs) cannabis growers from 18 countries (n=11,479). We describe their growing practices and use of chemicals and employ logistic regression to explore predictors of chemical use. We also compare chemical use in our 2020-21 sample with that from our 2012-13 data in the 3 countries (Australia, Denmark, UK) where respondents were asked about their use of growing chemicals in both surveys.

Results: In 2020-21, 26% of recent cannabis growers reported use of chemicals. Growers who were at highest odds of using chemicals were male, older, living in urban/cities, not growing for environmental reasons, growing in order to sell, growing where they believed cannabis was legal, and growing under artificial light in soil or non-soil media. We found significant reductions in the proportions of our samples who reported using chemical fertilizers in the 3 countries where we collected data in both waves.

Conclusion: Growers using soil and artificial light comprised over half of all the chemical users in the sample. Efforts at informing and educating growers about the problems of chemical fertilizer, nutrient and pesticide use should include all growers including those who grow in soil under artificial light. Possible explanations for the apparent decrease in chemical use from our 2012-13 to 2020-21 samples are discussed. Stricter regulation of the legal cannabis fertilizer market is required to empower growers to reduce the toxicity of cannabis they grow, distribute and consume.

[298 words]

Introduction

In 2021, worldwide, 219 million people are estimated to have used cannabis in the past 12 months (UNODC, 2023). In the past 10 years, cannabis use has been legalized in a number of countries for medical use and a handful of countries for non-medical use, but non-medical use remains illegal in most parts of the world and subject to the UN conventions (Decorte, Lenton, & Wilkins, 2020). Over the last 40 years cannabis cultivation techniques have changed substantially, with increased indoor growing under lights and the use of hydroponic methods. These changes have facilitated indoor domestic cultivation in many developed countries, which has reduced reliance on cannabis imported from 'traditional producer countries' (Decorte & Potter, 2015). Over 2012-2019, international data indicates that the increase in indoor cannabis cultivation was greater than that of outdoor cultivation, with 65 countries that reporting indoor cannabis cultivation to UNODC in 2019 (UNODC, 2021).

Previous research by our research collaboration based on data from 1722 growers in 3 countries (Australia, Denmark, and the UK) showed that many cannabis growers use 'nutrients', fertilizers and other horticultural chemical products, hereafter termed 'chemicals', that are marketed towards cannabis growers, sold online and in 'grow shops' (Lenton, Frank, Barratt, Potter, & Decorte, 2018). These products, are manufactured by a legal industry, estimated to be worth USD 201.86 million in 2022 (Singh, 2023), that flies under the regulatory radar. They have names designed to appeal to cannabis growers, such as 'Big Bud', 'Bloombastic', 'Nirvana', 'Monsta Bud' and 'Dutch Master' (Lenton, et al., 2018). This research suggested that, in many cases, the labels on these products misrepresent their true contents (Lenton, et al., 2018), masking the fact that many products contain hazardous chemicals, notably pesticides and Plant Growth Regulators (PGRs) (Hermes, 2011; Sirius, 2016). PGRs are used in illegal cannabis cultivation because they produce smaller plants with a higher concentration of larger flowers or 'buds' (Subritzky, Pettigrew, & Lenton, 2017). Buds are the part of the cannabis plant with the highest tetrahydrocannabinol (THC, the main psychoactive compound) content and comprise the bulk of cannabis sold and consumed for its psychoactive properties. PGRs increase the yield of buds per plant and per unit of growing area (Manic Botanix, undated; Subritzky, et al., 2017), making them particularly attractive to indoor growers and those that want to sell their cannabis, even though they produce buds with fewer terpenes and cannabinoids and, consequently, lower potency (Stumper, 2022).

Health concerns

Most PGRs have been banned in mainstream legal agriculture for decades due to their toxicity (Hermes, 2011). Notable PGRs, daminozide (Alar) and paclobutrazol, have been found unlabelled in nutrient solutions targeting cannabis growers and sold online and in grow shops and hydroponic equipment stores in the US (Hermes, 2011). Paclobutrazol has been shown to affect neurotransmitter systems in rodent models (e.g. Xu & Yang, 2020), disrupt spermatogenesis, affect development in several fish species, and produce toxicity, likely via accumulation in the brain (Li, et al., 2012). However, little is known about the health consequences to humans from chronic exposure (Montoya, Conroy, Vanden Heuvel, Pauli, & Park, 2020) as would be seen among people who regularly use cannabis. Daminozide is classified as a Group B2 Probable Human Carcinogen (National Center for Biotechnology Information, 2022). Paclobutrazol has been banned from use on food, and as a consequence, no maximum levels of exposure have been established for agricultural products in the US (Massachusetts Department of Agricultural Resources, 2012). Evidence suggests that some 70% of the chemical residues (including paclobutrazol) on plant material can be transferred to mainstream smoke (Sullivan, Elzinga, & Raber, 2013). Furthermore, burning pesticide chemicals while smoking can produce highly toxic pyrolysis products (Atapattu & Johnson, 2020).

So, while some people who use cannabis choose to grow their own plants to produce ‘healthier’ cannabis (Potter, et al., 2015), many growers using these nutrient and fertilizer products may be unwittingly introducing hazardous chemicals into the cannabis they grow, consume and supply to others due to inaccurate labelling which claims the products to be ‘natural’, when many contain these toxic chemicals. Indeed, cannabis plants readily absorb toxins and are recognized as *hyperaccumulators* of pesticides, toxins, heavy metals, radioactive elements and hydrocarbons and for that reason are proposed as ideal plants for phytoremediation of contaminated soils and environments (Bengyella, Kuddus, Mukherjee, Fonmboh, & Kaminski, 2022). Hyperaccumulators are plants which can absorb and accumulate heavy metals in their leaves and other above-ground sections at values exceeding specific metal thresholds (Sytar, Ghosh, Malinska, Zivcak, & Brestic, 2021)

Advocates within the cannabis growing and using community in North America (e.g. Integral Hydroponics, 2015; Manic Botanix, undated; Sirius, 2016) were instrumental in raising concerns about these products and prompting regulatory interest. Early testing of cannabis products in both emerging legal and established 'tolerated' cannabis markets revealed high rates of contamination with these chemicals, for example in Californian medical cannabis patients (Sullivan, et al., 2013), many of whom were at increased vulnerability due to their illnesses (McPartland & Pruitt, 1997), and 'cannabis coffeeshops' in the Netherlands (Venhuis & van de Nobelen, 2015). Subsequently, millions of dollars of legal cannabis products were destroyed in Canada (Robertson, 2017) and Colorado (Migoya, 2017) because they were contaminated with myclobutanil, a fungicide that has been found to produce cyanide on combustion (Health Canada, 2017). Many commercial formulations of pesticides targeted at cannabis growers comprise a mix compounds from a variety of chemical classes in one product (Taylor & Birkett, 2020), and can be detected in cannabis often at levels well in excess of those allowable in any legally available agricultural product (Voelker & Holmes., 2015).

Regulation

Pesticides, fertilizers and nutrient products are subject to legal regulatory control in many countries, yet there are reasons to doubt the regulatory effectiveness in the cannabis growing focussed market, particularly where cannabis cultivation is illegal. For example, in California in 2010 it was reported that hydroponic stores had repackaged pesticides (e.g. bifenazate and abamectin) for sale to cannabis growers, that were only approved for use on landscape plants but not on plants grown for human consumption (McPartland & McKernan, 2017). In Australia, chemicals such as PGRs must be registered with the Australian Pesticide and Veterinary Medicine Authority (APVMA) before they can be legally supplied via brick-and-mortar stores or online retailers, with fines enforced for supply of unregistered products. While regulations exist 'on the books' it is unclear how rigorously they are enforced. In many countries, even if those who illegally grow cannabis want to ensure they produce contaminant-free cannabis for themselves and their peers, poor product labelling makes it hard to identify a regulatory breach. Furthermore, where a grower in an illegal market determines that their nutrient supplier is selling products in breach of the regulations, it is unlikely they will risk identifying themselves to the authorities by registering a complaint. Additionally, toxicological studies submitted as part of product registration rarely consider all potential end-market uses, such as combustion that will occur as part of cannabis consumption. Finally, the capacity for authorities to effectively monitor the large volume of online sales, many of which may be cross-border, is questionable.

Cannabis growing practices

There are many online sources of information on cannabis growing and use of different growing locations (indoor and outdoor), grow media (soil and non-soil), lighting (sunlight and various forms of artificial light) and other equipment (Lenton, et al., 2018). There are also various techniques and different garden styles which are used to maximize the exposure to light and produce the highest yield of flowering heads. These include hydroponic and related cultivation techniques (e.g., ebb and flow watering, deep water culture, aeroponics) and methods of plant training (topping, training, pruning, etc.) (Lenton, et al., 2018).

Our previous study, which asked growers in Australia, Denmark and the UK about their growing practices, found that unsurprisingly, because of climate and open space, Soil and Sunshine (Soil – Natural Light; S-NL) growing was more common in Australia (55.6%) than in Denmark (44.7%) and the UK (10.3%), while Soil and Artificial Light (S-AL) growing was more common in the UK (67.7%) and Denmark (44.7%) compared to Australia (28.5%). Growing hydroponically (Non Soil – Artificial Light; NS-AL) was reported by a higher proportion of respondents in the UK (22.0%) comparted to Australia (15.9%) or Denmark (10.7%). There were also significant differences between countries across most growing locations, with most of these seemingly associated with climate and issues of space and population density in the three countries. Chemicals were significantly more likely to be used by respondents from the UK (61.0%) and Australia (45.3%) than those from Denmark (34.6%). Biivariate comparisons suggested use of chemicals was significantly more common among those: who grew to sell, male growers, grew using artificial lights (NS-AL and S-AL), had a growing area of 3 square meters or less, communicated with growers online, and were slightly older than those who did not. However, multivariate analysis suggested that the only unique predictor of the use of chemicals was grow method. Specifically, compared to those who grew in soil and sunshine (S-NL), respondents who grew in soil under artificial lights (S-AL) were at 2.86 greater odds of using chemicals and those employing hydroponic methods (NS-AL) were at 11.89 greater odds of using chemicals.

The current paper

This paper describes the cannabis growing practices of mainly small-scale cannabis growers in 18 countries, with particular focus on their self-reported use of chemicals (chemical fertilizers, pesticides and 'nutrients') and exploring the predictors of chemical use. Presenting results on growing practices (separate to chemical use) is important because since our 2012-13 data collection (Lenton, et al., 2018) there have been developments in equipment (e.g. LED lighting) and growing practices are key variables likely to be related to chemical use. We also compare chemical use in our 2020-21 sample with that from our 2012-13 data (Lenton, et al., 2018) in the 3 countries (Australia, Denmark, UK) where web survey respondents were asked about their use of growing chemicals in both surveys. These issues have clear policy implications regarding regulation in both the expanding legal cannabis market and the grey market for pesticides, fertilizers and nutrients targeting people who grow cannabis. They are also relevant to individual cannabis growers regarding the choices they make about what fertilizers and nutrients they use on their plants, and people who use cannabis making informed choices about the cannabis they consume.

Method

Data comprised responses to the International Cannabis Cultivation Questionnaire (ICCQ 2), a convenience web survey developed by the Global Cannabis Cultivation Research Consortium (GCCRC) (2023) to measure and compare patterns of mainly small-scale cannabis cultivation across different countries (Global Cannabis Cultivation Research Consortium, 2023). The data protocol is registered and available (Lenton, et al., 2023). The study method was closely based on that described in detail from the earlier phase 1 survey (ICCQ 1) conducted in 2012-13 (Barratt, et al., 2012; Barratt, et al., 2015) in 11 countries. In the most recent survey, using the ICCQ 2, data were collected in 18 countries in 12 languages, from August 2020 to September 2021. We used a broad-based recruitment strategy to maximize the heterogeneity of respondents including an international project website (www.worldwideweed.nl), Facebook groups, Twitter, online forums, drug policy influencers, mainstream media, street press advertisements, and flyers distributed at festivals, grow shops and university campuses. Once directed to the project website (www.worldwideweed.nl), potential respondents could choose the survey and language associated with their country of residence (see also Barratt, et al., 2015). Eligibility criteria for inclusion in the analysis were that the participants had to be at least 18 years of age, had grown cannabis during the past five years, and had completed at least 50% of the ICCQ 2 core questionnaire (Global Cannabis Cultivation Research Consortium, 2023). Where required, ethical approval was sought and granted in each of the participating countries (usually at the institutions of the lead GCCRC member for that country). As we have described elsewhere (Barratt, et al., 2012), IP addresses were not collected because familiarity with the target group and piloting emphasized the importance of anonymity and this was noted in ethics committee applications. A duplicate cases analysis indicated only 49 duplicates (0.4% of cases). These were removed from the data set resulting in the final N of 11,479 eligible responses.

The ICCQ 2 included 40 core questions on: experiences with growing cannabis; methods (including use of fertilizers, pesticides and other chemicals) and scale of growing operations; reasons for growing; personal use of cannabis and other drugs; demographic characteristics of growers; contact with the criminal justice system, and participation in cannabis and other drug markets. In addition to the core questionnaire, specific optional and specialized modules were offered to participants in different countries based on perceived relevance and topicality.

Specifically, in the current survey, respondents were asked: “What fertilizers, supplements (e.g. growth agents, bud stimulators) or insecticides do you typically use?” The response options (unnumbered in the online survey) were: (1) Organic fertilizers, supplements or insecticides; (2) Chemical fertilizers, supplements or insecticides; (3) Both organic and chemical fertilizers, supplements or insecticides; (4).

I do not use any fertilizers, supplements or insecticides; and then Don’t know or Prefer not to say options. Respondents who answered 2 or 3 above were coded as having used chemical fertilizers for this analysis.

Unlike in the 2012-13 survey, we did not ask growers to specify the brand of fertilizer they used. While on face value this would seem important to identify use of chemicals such as PGRs, in our previous survey we found incomplete labelling and failed to find products listed on online organic certification systems in various countries prevented us from determining which products contained PGRs and which did not (Lenton, et al., 2018). Furthermore, hydroponics and cannabis toxicology experts we consulted expressed the opinion that identifying PGRs via brand names was an impossible task due to inadequate or mislabelling (Lenton, et al., 2018). Further, as this question was asked to all respondents in the core questionnaire, rather than in an optional module as in 2012-13, time and space constraints precluded it.

The current analysis focuses on respondent demographics, methods and scale of growing operations, and reasons for growing from the ICCQ, along with questions from the optional Growing Methods module which included questions addressing typical type of lighting and other equipment used, where growing took place, hours per week spent on growing, weeks to produce a crop and the typical number of plants grown. Overall, the Growing Methods module was offered to respondents in 10 Countries (Australia, Austria, Canada, France, Georgia, Germany, Italy, Switzerland, UK, USA) and completed by a subsample of 5564 individuals. There was a further module targeting harvesting and processing, but as the countries completing the Growing and Harvesting modules were not the same, this data will be presented in a separate paper.

Analysis

For bivariate analyses (chi square for categorical variables, ANOVA, and t-test for continuous variables) a conservative alpha level of $p < 0.01$ was applied to account for the possibility of type 1 error due to multiple comparisons.

Bivariate predictors of the use of chemical fertilizers, supplements, and insecticides were subsequently subjected to multivariate analysis with a binomial logistic regression to explore their unique relationship with the use of chemicals where inter-correlation was accounted for. That is, for example, if both *growing indoors* and *grow method* (including hydroponic growing) where shown to be highly predictive of use of chemicals by univariate analysis, the multivariate analysis will show which of those highly correlated predictors was responsible for the greatest amount of variance in use of chemicals to help inform interventions to reduce risk. Multivariate logistic regression with cluster robust standard errors (by country) (Long & Freese, 2014) was employed to analyze the use of chemical fertilizers, controlling for a range of theoretically and empirically relevant covariates. To assess logistic regression model fit, we consider a *C*-statistic of $0.7 \leq C < 0.8$ to be acceptable and $0.8 \leq C < 0.9$ to be excellent (Giancristofaro & Salmaso, 2003). We also examined the presence of multicollinearity using the variance inflation factor (VIF), where VIF < 3 is good and VIF < 5 is acceptable. When presenting the results of the logistic regression analyses, we report odds ratios (ORs) in the table. We adopted a $p < .05$ criterion for determining statistical significance of predictors. Discussion of specific effects implies holding all other variables constant.

Decisions as to what variables were included in the logistic regression were based on an exploration of bivariate relationships between the predictors and criterion variable (Chemical use yes/no) (see Table 5) and what was known from other analyses including our own (Lenton, et al., 2018) and comprised a different and larger set of potential predictors than that earlier work. Most independent variables in the logistic regression were categorical, rather than continuous. But for ease of interpretation, where it made conceptual sense, both continuous and categorical variables with more than two values were dichotomized or trichotomized. The exception to this was the age variable which was continuous. Decisions about at which values the variables should be treated thus were based on an inspection of the distribution of values on the raw values of the variables, along with what made sense from a conceptual point of view (e.g., any employment ('FT, PT, or casual') vs 'none'). In this analysis we have clustered standard errors by country. The variables entered into the logistic regression equations (see Table 5) were: Gender, Age (continuous), Employment (Y/N), Urbanicity (trichotomized), Education (trichotomized), Selling as a reason to grow (Y/N), Grow area (dichotomized), Number of mature plants typically grow per crop (trichotomized), Total crops grown (trichotomized), Mainly grow outdoors

(Y/N), Perceived legality of growing (trichotomized), and Grow method (soil under natural sunlight (S-NL); soil under artificial light (S-AL); non-soil under artificial light (NS-AL) and non-soil under natural light (NS-NL). The listwise deletion of cases produced an analytic sample for the logistic regression analysis of *N*=4180.

Results

Demographic characteristics

Table 1 presents the demographic characteristics by country of the whole sample (N =11,479). Due to the large sample size there were significant country by country differences on all variables. While the sample was predominantly male (85.8%) there was a noticeably lower proportion of males in New Zealand (60.9%). Furthermore, though the overall median age was 37 (range 18-80) it varied from a high of 53 in the US to a low of 24 in Italy.

Growing method and scale

Table 2 presents the results of the growing method and scale questions which were also asked for the whole sample (N=11,479). Again, while there were differences between countries, those make sense from a climate and growing opportunity perspective, as shown in Supplementary Table S1. Overall, 40.5% of the sample said they exclusively grew indoors. Some 80.4% of respondents grew their plants in living organic soil as opposed to in water (hydroponics) (6.3%) or other grow media. While 56.4% reported only using organic additives, 8.7% of respondents reported only using chemical fertilizers, supplements, and insecticides, with 17.9% using both chemical and organic additives. Most respondents (80.6%) reported they grew no more than 6 mature plants per crop, 8.7% grew 7-10 mature plants and 10.7% more than 10. Over half (55.9%) reported growing in an area of not more than 3squ metres. Only 7.1% of respondents said that selling was one of the reasons they grew.

Results from the Optional Growing Methods Module

Data from the optional growing method and scale questions which were asked of respondents in 10 countries is presented in Tables 3-5 and by country in Supplementary Tables S1-S3. Table 3 presents growing methods, lighting and other equipment used. Growing in soil and artificial light (S-AL) was the most popular typical method (57.6%), followed by soil and sunlight (S-NL) (23.6%) reported by more respondents than the hydroponic method (NS-AL) (17.4%). Interestingly, when asked to identify what kinds of lighting they typically used, more respondents identified LED lamps (57.3%) than sunlight (51.3%) in this multiple response variable. Overall respondents who used artificial lighting reported that they used a median total wattage of 400 Watts (IQR 200-700 Watts). The list of other equipment used by respondents was vast, with Timer unit (63.6%), Oscillating fan (56.7%) and Grow tent (56.3%) used by over half the respondents to this module. Typical grow location is presented in Table 4. Growing outside on one's own property was identified by a just over third (34.3%) of respondents, closely followed by growing in a house/apartment room used for other things (29.7%).

Variables associated with chemical use

Bivariate comparisons of variables associated with the use of chemical fertilizers, supplements, and insecticides are, presented in Table 5. to examine the factors related to use of these chemicals. This suggests that there were differences according to the gender ($\chi2$ = 11.47, df=2, p = .003), age (t = -6.173, df=4178, p < .001), education level ($\chi2$ = 21.83, df=2, p < .001) and urbanicity ($\chi2$ = 33.87, df=2, p < .001) of the respondent, whether they grew for environmental reasons ($\chi2$ = 33.49, df=1, p < .001), whether selling was a reason to grow ($\chi2$ = 19.58, df=1, p < .001), the total grow area ($\chi2$ = 4.77, df=1, p = .029), the typical number of lifetime grows ($\chi2$ = 14.78, df=2, p = 0.001), the grow method used ($\chi2$ = 618.43, df=3, p < .001), whether they mainly grew outside ($\chi2$ = 98.07, df=1, p < .001) and the perceived legality of cannabis growing where they grew ($\chi2$ = 55.50, df=2, p < .001). With regards to grow method used, although the proportion of NS-AL (hydroponic) growers who were using chemicals was greater (65.4%) than those who were growing in S-AL (25.5%), the greater number of soil growers meant the numbers of chemical users in that category (n=629) was greater than the chemical users in the hydro group (n=508).

The binomial logistic regression analysis presented in Table 6 showed that when controlling for the effect of all these other variables and clustering by country, the use of chemical fertilizers, nutrients and supplements was predicted by gender, age, urbanicity, growing for environmental reasons, selling as a reason to grow, grow method, and the perceived legality of cannabis where they grew. Specifically, controlling for all other predictors: males had 1.50 times greater odds than females of using chemicals; for each additional year of age respondents had 1.01 times greater odds of using chemicals; compared to urban/city dwellers, those in suburban areas were at 16% smaller odds, and those in rural areas were at 30% smaller odds, of reporting use of chemicals. Those who grew for environmental reasons were at 30% smaller odds of reporting chemical use; and those who said that selling was a reason to grow were 1.64 times greater odds of reporting chemical use than those who did not. Those that said they grew in S-AL were at 2.18 times greater odds of using chemical fertilizers than those who grew in S-NL; and those who grew using hydroponic methods (NS-AL) were at 11.20 times greater odds of using chemical fertilizers than those who grew in S-NL. Those who grew in a legal environment where any adult use (both medical and recreational) was legal, were 1.74 times greater odds of reporting use of chemicals than those in a full prohibition environment. None of the other predictors in the final model reached significance.

Comparisons between countries and survey years in self-reported chemical use

Figure 1 presents the proportion of respondents who responded that they used any chemical fertilizers, supplements, or insecticides, for both the 18 countries in the current sample and the four countries that reported on this question in the optional module in the 2012-13 data collection. While there are obvious country by country differences, what is noteworthy is the significant reduction in the proportion of growers reporting use of these chemicals in the three countries for whom we have data for both years. Using non-parametric statistics, the overall by year difference was significant ($\chi 2 = 10.470$, df=2, $p< .005$) and for each of these countries by year as well (Australia: $\chi 2 = 54.577$, df=1, $p< .001$; Denmark: $\chi 2 = 9.628$, df=1, $p= .002$; GBR: $\chi 2 = 103.623$, df=1, $p< .001$).

Discussion

Grow method and scale

We successfully surveyed a large international sample of predominately small-scale growers, with 4 in 5 of the sample growing not more than 6 mature plants per crop. As in 2012-13 (Lenton, et al., 2018), we again found that roughly 4 in 5 respondents grew their plants in organic soil, and for almost 6 in 10 of the sample who completed the optional grow methods module cannabis growing was done in soil under artificial light (S-AL), higher than the less than 5 in 10 we found in the three countries we asked the question of in 2012-13 (Lenton, et al., 2018). For climatic reasons, lack of access to an outdoor growing space, growing control, and avoiding detection, it is unsurprising that much of the soil growing is done indoors under artificial light. Although we have again found, as we did in 2012-13 (Lenton, et al., 2018) that growing by the hydroponic (NS-AL) method was used by less than 1 in 5 growers in our samples.

As we found in 2012-13 (Lenton, et al., 2018), and as previously noted by Decorte (2010), the use of 'sophisticated' growing techniques and equipment was common in our sample. For example, over 6 in 10 of those who completed the grow methods module used timer units, more than half reported use of grow tents and oscillating fans, and almost half used thermometers, extractor fans, carbon filters and pH test kits. This suggests, again, that having growing equipment in place should not be taken as indication of a professional, commercial, or organized crime type of growing operation (Decorte, 2010; Lenton, et al., 2018; Potter & Klein, 2020) In Italy, for instance, the use of rudimentary/non-sophisticated techniques is necessary to avoid criminal sanctions for cultivating cannabis (Fiorentini, 2019). Particularly with the growth of online sources providing advice and instructions in such things, increasingly what has been viewed as 'sophisticated' equipment by law enforcement and others, is common for your average, small-time cannabis grower in this sample. Furthermore, developments in lighting, such as low-voltage full-spectrum (like sunlight) LEDs, now available from most hardware stores and residential lighting shops, means that growers don't have to use high voltage and heat producing light sources such as high-pressure sodium and metal halide lamps which were previously more common in our 2012-13 sample. Presumably, this has benefits for the safety of indoor grows as well as the power load and heat signature that was previously reported to be used by law enforcement in some countries to detect grow houses (Potter & Chatwin, 2012; Potter & Klein, 2020)

Predictors of chemical use

As we found in the earlier study (Lenton, et al., 2018), growers using hydroponic methods (NS-AL) were the most likely to use chemical fertilizers, but while soil and artificial light growers (S-AL) were close to 5 times less likely than the hydro group to use chemicals, their larger weight of numbers meant there were more chemical users in the S-AL group than the NS-AL group, and overall they comprised over half of all the chemical users in the sample. This suggests that efforts at informing and educating cannabis growers about the problems of chemical fertilizer, nutrient and pesticide use should not underestimate the importance of reaching growers who grow in soil under artificial light. Whereas in the 2012-13 study, the only significant multivariate predictors of chemical use was grow method, (NS-AL and S-AL) (Lenton, et al., 2018), in the current study we found that gender, age, urbanicity, growing for environmental reasons, selling as a reason to grow, grow method, and the perceived legality of cannabis where they grew, remained significant in the multivariate model. Some of these results reflect the addition of new questions in the questionnaire and a different pool of questions being added in the model, which is relevant for urbanicity, growing for environmental reasons, and the perceived legality of cannabis where they grew. However, selling as a reason to grow only managed to remain significant in the final model in the current study. Whether this reflects genuine changes, or simply a larger sample resulting in this remaining significant in the final model remains unclear. The findings with regards to growing methods remain the strongest and have been addressed above. The findings that those who grew to sell, and male growers, were significant independent predictors of chemical use makes sense on face value. Similarly, the fact that urban/city dwellers, versus those in suburban and rural areas, were more likely to use chemicals, separate to the grow method, could be due to a number of factors. These could include size of grow, not having access to an outdoor growing environment, maybe potentially higher levels of scrutiny/visibility by law enforcement and others in urban/city locations which may dispose someone toward more intensive and concealed crops, or potentially accessibility of grow shops selling chemical fertilizers. Clearly, more research is required to understand this finding.

Importantly, the finding that chemical use was more common among those that said they grew in an environment where medical or recreational growing was legal, compared to prohibited, was possibly unexpected by many on the assumption that legal environments are, by definition, more regulated and produce 'safer' products. However, as has previously been shown, in profit-driven commercially-oriented legal markets the desire of industry to make profit and avoid additional costs can override public health concerns (Lenton, 2020; Subritzky, Lenton, & Pettigrew, 2016; Subritzky, Pettigrew, & Lenton, 2016; Subritzky, et al., 2017). It is thus, perhaps unsurprising that the odds of chemical use were somewhat greater in environments where growing cannabis for medical reasons is legal and were even greater where growing for recreational use was also legal. We have seen in environments where cannabis use for medical and /or recreational reasons is legal, particularly those in North America, that there is a proliferation of all aspects of business associated with the drug, including outlets, advertising and promotion, cannabis industry employment, etc (Fischer, Daldegan-Bueno, & Boden, 2020; Subritzky, Lenton, & Pettigrew, 2016; Subritzky, Pettigrew, & Lenton, 2016). It is to be expected that in such environments the promotion and sale of cannabis specific growing products containing 'nutrients' and chemicals could perhaps be more common and normalized than in prohibited markets where such products are less available and less promoted. Whatever the case, this result suggests that jurisdictions contemplating legalization of medical or recreational cannabis cultivation should ensure they effectively regulate the cannabis nutrient and fertilizer industry, and inform people who grow and use cannabis about the risks of inappropriate or toxic chemical fertilizers on cannabis. As we have said above, regulation is made more challenging in markets where there is a considerable proportion of online sales and international importation..

Notwithstanding the findings of this multivariate analysis which identifies predictors of chemical fertilizer use, it is important to say that regulatory and educational efforts to inform growers about the problems of chemical fertilizer, nutrient and pesticide use should not be limited to those groups identified as more likely to use chemicals in this analysis. Furthermore, whether cannabis cultivation is legal or illegal, it is not enough to have cannabis nutrient and fertilizer product regulations 'on the books' — they need to be clear, enforceable and enforced.

Apparent decreases in use of chemicals

We did find significant reductions in the proportions of our samples who reported using chemical fertilizers from 2012 to 2020 in those three countries where we collected data in both waves (Australia, Denmark, and the UK). The caveat here is that these two data collections comprise different cross-sectional samples, rather than a longitudinal or repeated measures studies. It is unclear the extent to which the observed differences reflect methodological factors, such as, sample differences or the effect of social desirability on responses with people less likely to admit they use chemical fertilizers. Alternatively, the reported reduction in the use of chemicals could reflect more fundamental changes. These could include increased recognition among growers of problems associated with chemical fertilizer use as a result of their own research, advocacy by others including vendors selling fertilizers and nutrients, or demands for more healthy cannabis by cannabis consumers. Other factors such as the narrowing price differential and/or yield gap between organic and chemical products for horticulture (Brzozowski & Mazourek, 2018; Ponisio, et al., 2015), or the development of cultivars which are adapted to be treated without chemical products, could also be relevant.

In an anonymous online survey where IP addresses are not collected, one would think that factors such as social desirability would be less of a factor than in face-to-face research methods. Additionally, in recent years, we have seen user advocacy regarding the problems of PGRs in cannabis and how to recognize PGR affected cannabis in many countries building on that which was done earlier (Hermes, 2011; Manic Botanix, undated; Sirius, 2016) in North America. For example, in Australia there have been extensive efforts by cannabis advocates (Lagrasso, 2021; Lu, 2022) to inform and educate people who use and/or grow cannabis about the dangers of PGRs and how to identify cannabis that has been grown with them. In New Zealand there have been high profile drug alerts sent out to the drug using community regarding the issues (Drug Information and Alerts Aotearoa New Zealand (DIANZ), 2021). Cannabis advocates targeting German speaking countries have also been addressing PGRs (Weedhack Staff writer, 2023), as have medical cannabis prescribers in the USA (e.g. Dugar, 2022) and the cannabis press in the UK (Ledger, 2022). A number of commercial entities, such as one seed company from the Netherlands (Dutch Passion, 2023) and one based in Spain (Stumper, 2022), also have been providing information about PGRs. Further, some activists have reported witnessing a sea-change in consciousness about these issues among people who use and/or grow cannabis in recent years (e.g. Lagrasso, 2021). It is thus possible that our findings reflect a true reduction in the use of chemicals, which may be related to the advocacy/activism within the cannabis using and growing community, and potentially some retailers of cannabis targeted fertilizers and nutrients changing their advice and product offerings in response to grower demands.

Limitations

As we have previously noted (Lenton, et al., 2018) the primary limitation of this methodology is that it is a self-selected non-representative sample, and thus, cannot be used to draw conclusions about the broader population of cannabis cultivators.

Yet because cannabis growers often comprise a very small proportion of representative general population samples (Barratt & Lenton, 2015) and are a hidden and stigmatized population, we believe purposive sampling provides a valid and cost-effective means to explore this under-researched group. We also concede the potential criticism that we are not likely to get at large scale illegal growers who are such an important part of the market. However, we note that much of the previous research on cannabis growers has been done on law enforcement data which often includes these larger-scale growers and make the point that our primary target, even in a changing world with larger scale legal commercial growers in some countries, was the smaller scale growers. We also note the concern regarding multiple responders in web surveys of this sort, but this is more likely where there is some financial or other re-imbursement for participation, which we did not employ in this nor in our previous survey (Barratt, et al., 2015). It was again gratifying that when we applied the appropriate statistical tools to identify such cases that these were very small in number and, whilst we removed them from the final sample, most seemed to be a function of initial non-completers logging in again to complete the survey rather than apparent deliberate attempts to be double counted. As we noted above, for practical reasons, we did not ask growers to identify the brands of fertilizers which they used. We acknowledge that this is an important limitation of our work as we are not able to definitively say whether those respondents using chemical nutrients and fertilizers were using products containing PGRs, pesticides and other compounds which have been shown to be harmful to health. However, as we have noted, the presence of PGRs and other toxic chemicals in growing cannabis nutrients and fertilizers and being found in cannabis in the market continues to be an issue in many countries (Drug Information and Alerts Aotearoa New Zealand (DIANZ), 2021; Dugar, 2022; Dutch Passion, 2023; Lagrasso, 2021; Ledger, 2022; Lu, 2022; Stumper, 2022; Weedhack Staff writer, 2023). Furthermore, the way the question was asked, as explained in the Methods, does mean that it is in the 'chemicals' group where potentially harmful nutrients, fertilizers and pesticides will be found. Consequently, while the findings are not definitive regarding *risky* chemical use, they do point to which growers could be targeted with interventions to raise the issue to reduce risk. ~~may be seen as an omission and in~~Beyond this, in our future work we will continue to explore how we can usefully get more information on which products growers are using and with, better data on product contents, be able to draw stronger conclusions on the use of noxious chemicals.

Formatted: Font: Italic

Future research

It is encouraging to see the growth of recognition of the problems of synthetic PGRs in the cannabis using and growing community and the efforts from a number of advocacy and commercial entities to inform and educate growers and discuss the issue in various fora. However, we still have a significant international industry which is producing nutrient and fertilizer products for cannabis growers which remains ineffectively regulated with little-to-no enforcement of accuracy and transparency in product labelling. Many of these products have labels that misrepresent their true contents and contain chemicals that increase yield, but are toxic, and get into the cannabis which is consumed. One of the leading reasons why people who use cannabis choose to grow their own cannabis is to have control of the growing process and the product quality (Potter, et al., 2015), but if they cannot be certain of what is in the products that they use to grow their cannabis, they cannot reduce the toxic effects. This also means many people who are cultivating cannabis medicinally for sick family and friends with the belief they are helping (Hakkarainen, et al., 2015; Klein & Potter, 2018) may be harming them. We believe that future research should be done in two areas: Firstly, toxicological studies of the fertilizers and nutrients marketed to cannabis growers, and secondly, qualitative studies with cannabis growers which focuses on their use of nutrients and fertilizers. The former could involve (i) Purchasing a range of nutrient and fertilizer products targeted at people who grow cannabis, (ii) Chemical analysis of those products using state-of-the art liquid chromatography mass spectrometry (LC-MS) to identify PGRs and other potentially toxic chemicals in these products, and (iii) Compare those contents to the descriptions of product contents on product labels, websites and associated documents. The qualitative research could comprise interviews with cannabis growers with a particular focus on their practices of using chemicals/nutrients/fertilizers, to explore their motives for using these products, their knowledge about these products, their main supply channels for acquiring these products, their awareness of the risks involved, and their beliefs regarding these growing practices. In our view such toxicological and qualitative research is needed to complement and inform the growing community advocacy on this important harm reduction topic. Cannabis growers have a right to know what chemicals are in the products that are marketed and sold to enhance their crops whether they operate in legal or illegal, cannabis markets. People who use cannabis have a right to know what harmful additives may exist in the cannabis that they buy and consume whether from legal or illegal markets.

Conflict of interest

No conflict declared.

Acknowledgements

We would like to thank the many thousands of cannabis cultivators who have completed our online questionnaires and contributed their knowledge and experience to this work. Our research would not be possible without their efforts. Thanks also to all the people and organizations who supported and promoted our research, and all the *coffeeshops*, grow shops and headshops that helped us. Thanks to all our colleagues from the GCCRC who contributed to the design, conduct and analysis of the questionnaire. An earlier version of this paper was presented at the International Society for the Study of Drug Policy Conference in Leuven, Belgium, in 2023.

Supplementary Tables

Supplementary tables referred to in this article can be found at: [Web archive for IJDP]

Table 1: Demographic characteristics by country

	AUS	AUT	BEL	CAN	CHE	DEN	DEU	FIN	FRA	TOTAL	Sig.
Gender %	(n=723)	(n=44)	(n=2,084)	(n=513)	(n=277)	(n=873)	(n=787)	(n=524)	(n=681)	(N=11,308)	<.001
Male	82.0%	79.5%	89.6%	83.4%	88.4%	80.6%	92.0%	88.9%	92.1%	85.8%	
Female	17.6%	13.6%	10.0%	15.4%	10.1%	18.7%	7.2%	10.1%	6.8%	13.3	
Non-binary	0.4%	6.8%	0.3%	1.2%	1.4%	0.7%	0.8%	1.0%	1.2%	0.8	
Age in yrs.	(n=732)	(n=44)	(n=2,107)	(n=519)	(n=282)	(n=883)	(n=801)	(n=536)	(n=690)	(N=11,479)	<.001
Median	46	34	33	41	37	40	33	36	36	37	
Mean	45.6	36.5	34.3	42.5	39	41.9	34.4	37.2	38	39.1	
IQR	35-56	26-47	25-41	33-51	29-49	29-53	25-41	29-44	29-45	27-49	
Range	18-80	18-71	18-80	18-77	18-74	18-80	18-77	18-70	18-75	18-80	
Currently Studying %	(n=638)	(n=43)	(n=1,899)	(n=475)	(n=247)	(n=787)	(n=725)	(n=500)	(n=616)	(N=10,217)	<.001
Full Time	4.4%	11.6%	16.0%	5.9%	7.3%	12.2%	13.1%	12.8%	8.0%	12.0%	
Part time	12.2%	9.3%	8.7%	8.2%	9.7%	2.7%	4.1%	9.0%	5.2%	9.5%	
Not studying	83.4%	79.1%	75.3%	85.9%	83.0%	85.1%	82.8%	78.2%	86.9%	78.4%	
Currently employed %	(n=638)	(n=42)	(n=1,884)	(n=477)	(n=251)	(n=790)	(n=736)	(n=496)	(n=610)	(N=10,211)	<.001
Yes	52.5%	69.0%	69.0%	66.9%	69.3%	53.3%	68.1%	47.6%	62.5%	58.2%	

	GBR	GEO	ISR	ITA	NLD	NZL	PRT	URY	USA	TOTAL	
Gender %	(n=340)	(n=215)	(n=87)	(n=1,350)	(n=355)	(n=197)	(n=111)	(n=340)	(n=1,807)	(N=11,308)	<.001
Male	83.2%	94.0%	90.8%	87.5%	85.4%	60.9%	87.4%	77.1%	82.3%	85.8%	
Female	16.5%	5.1%	9.2%	11.5%	13.8%	36.0%	11.7%	21.8%	17.0%	13.4%	
Non-binary	0.3%	0.9%	0.0%	1.0%	0.8%	3.0%	0.9%	1.2%	0.6%	0.8%	
Age in yrs.	(n=341)	(n=218)	(n=87)	(n=1,400)	(n=359)	(n=198)	(n=114)	(n=342)	(n=1,826)	(N=11,479)	<.001
Median	47	29	28	24	42	47	31	28	53	37	
Mean	47.2	30.6	30.2	27.8	42.5	47.4	33.2	30.9	51.7	39.1	
IQR	39-55	24-36	23-35	20-33	31-53	37-57	26-40	22-36	40-63	27-49	
Range	18-80	18-60	18-68	18-69	18-79	20-79	19-70	18-77	18-80	18-80	
Currently Studying %	(n=309)	(n=164)	(n=71)	(n=1,235)	(n=312)	(n=183)	(n=111)	(n=265)	(n=1,637)	(N=10,217)	<.001
Full Time	2.6%	12.8%	18.3%	30.2%	8.0%	4.4%	13.5%	11.3%	3.0%	12.0%	
Part time	8.4%	18.3%	21.1%	13.8%	9.0%	10.4%	16.2%	35.1%	8.4%	9.5%	
Not studying	89.0%	68.9%	60.6%	56.0%	83.0%	85.2%	82.8%	53.6%	88.6%	78.4%	

Currently employed %	(n=310)	(n=165)	(n=69)	(n=1,241)	(n=304)	(n=182)	(n=109)	(n=265)	(n=1,642)	(N=10,211)	<.001
Yes	55.5%	55.2%	58.0%	47.1%	57.9%	50.0%	70.6%	66.8%	50.9%	58.2%	

Table 2: Growing method and scale

Grows indoors or outdoors	n	%
Indoors	4,611	40.5
Indoors and outdoors	2,895	25.4
Outdoors (including greenhouses)	2,288	20.1
Seedlings grown indoors, then planted outdoors	1,600	14.0
Total	11,394	100.0
Usual root medium	n	%
Living organic soil	9,156	80.4
Water (i.e., hydroponic)	715	6.3
Coco coir/coconut	379	3.3
Organic/nonorganic mix	347	3.0
Perlite	329	2.9
Soil and organic mediums	236	2.1
Air (e.g. nutrient mist)	50	0.4
Rock wool	32	0.3
Unspecified mix/substrate	35	0.3
Nonorganic mediums	23	0.2
Varies indoor/outdoor	20	0.2
Multiple/mixed mediums	27	0.2
Other medium	23	0.2
Varies by growth stage	11	0.1
Total	11,383	100.0
Fertilizers, supplements or insecticides typically used	n	%
Organic only	6,360	56.4
Chemical only	976	8.7
Both	2,018	17.9
None	1,920	17.0
Total	11,274	100.0
Growing area (dichotomized)	n	%
up to 3 sqm	5,380	55.9
over 3 sq m	4,246	44.1
Total	9,626	100.0
Mature plants typically grow per crop	n	%
1-6	9,070	80.6
7-10	981	8.7
More than 10	1,200	10.7
Total	11,251	100.0
Selling as a reason I grow	n	%
No	10,641	92.9
Yes	817	7.1
Total	11,458	100.0

Table 3: Grow method, lighting and other equipment used.

Grow method (light source x grow medium)	n	%
soil & artificial light (S-AL)	3,173	57.6
soil & sunlight (S-NL)	1,299	23.6
non-soil & artificial light (NS-AL)	956	17.4
non-soil & sunlight (NS-NL)	81	1.5
Total	5,509	100.0
Lighting source*	n	%
LED lamps	3,166	57.3
Sunlight	2,837	51.3
High pressure sodium lamps	1,056	19.1
Metal halide lamps	525	9.5
Fluorescent lamps	514	9.3
Energy saving lamps	208	3.8
UV lamps	203	3.7
LEC lamps	5	0.1
Other	15	0.3
Total N	5,529	
Other Equipment & materials*	n	%
Timer unit	3,354	63.6
Oscillating fan	2,993	56.7
Grow tent	2,969	56.3
Thermometer	2,569	48.7
Extractor fan	2,518	47.7
Carbon filter	2,514	47.7
PH test kit	2,501	47.4
Light reflective wall lining	2,269	43.0
Growing substrates	2,130	40.4
Exhaust system	1,697	32.2
Inlet fan	1,655	31.4
Water pump	762	14.4
Air pump	678	12.9
Fan silencer/dampener	628	11.9
Water heater	211	4.0
Humidifier	72	1.4
Dehumidifier	76	1.4
monitors/controllers	69	1.3
EC/TDS meter	45	0.9
Hygrometer	35	0.7
Heater	26	0.5
Aircon - cooler	23	0.4
CO2 source	22	0.4
Other	145	2.7
No other equipment/materials	921	17.5
Total N	5,275	

* Multiple responses were possible

Table 4: Typical grow location

Location where typically grow*	n	%
Outdoors, on own property	1,805	34.3
In a house/apartment room used for other things	1,563	29.7
In a basement/cellar	741	14.1
In a house/apartment dedicated grow room	724	13.7
Inside a cupboard/closet	631	12.0
On a balcony	525	10.0
In a greenhouse	470	8.9
Outdoors, on public or state-owned land	329	6.2
Inside a shed	309	5.9
Outdoors, on other private property	292	5.5
In an attic/loft	161	3.1
In a warehouse	85	1.6
In a garage	45	0.9
In a grow house	40	0.8
Other	42	0.8
Total N	5,275	

* Multiple responses were possible

Table 5: Variables associated with use of chemicals*

	No Chemicals	Use Chemicals	Total	Sig.
Gender %	(n=2922)	(n=1258)	(n=4180)	.003
Male	69.0%	31.0%	100.0%	
Female	76.4%	23.6%	100.0%	
Non-Binary	68.0%	32.0%	100.0%	
Total	69.9%	30.1%	100.0%	
Urbanicity%	(n=2922)	(n=1258)	(n=4180)	< .001
Urban/City	65.7%	34.3%	100.0%	
Suburban	70.3%	29.7%	100.0%	
Rural	76.0%	24.0%	100.0%	
Total	69.9%	30.1%	100.0%	
Age (yrs)	(n=2922)	(n=1258)	(n=4180)	
Median	40	42	40	
Mean Age	41.3	44.5	42.3	< .001
IQR	28-53	33-56	30-54	
Range	18-80	18-80	18-80	
Education %	(n=2922)	(n=1258)	(n=4180)	< .001
Less than High school	79.3%	20.7%	100.0%	
High school or equivalent	69.2%	30.7%	100.0%	
College or above	68.1%	31.9%	100.0%	
Total	69.9%	30.1%	100.0%	
Employment %	(n=2922)	(n=1258)	(n=4180)	.333
Not employed	72.1%	29.9%	100.0%	
Employed incl. self employed	69.3%	30.7%	100.0%	
Total	71.0%	29.0%	100.0%	
Grows for environmental reasons %	(n=2922)	(n=1258)	(n=4180)	< .001
No	67.7%	32.3%	100.0%	
Yes	77.4%	22.6%	100.0%	
Total	69.9%	30.1%	100.0%	
Grow to Sell %	(n=2922)	(n=1258)	(n=4180)	< .001
No	70.8%	29.2%	100.0%	
Yes	59.1%	40.9%	100.0%	
Total	69.9%	30.1%	100.0%	
Grow area %	(n=2922)	(n=1258)	(n=4180)	.029
Up to $3m^2$	68.6%	31.4%	100.0%	
Over $3m^2$	71.7%	28.3%	100.0%	
Total	69.0%	30.1%	100.0%	

* Due to listwise deletion the N for this table is 4180

Table 5: Variables associated with use of chemicals cont.*

	No Chemicals	Use Chemicals	Total	Sig.
Typical mature plants per crop %	(n=2922)	(n=1258)	(n=4180)	.088
6 or less	70.6%	29.4%	100.0%	
7 to 10	69.8%	30.2%	100.0%	
More than 10	65.8%	34.2%	100.0%	
Total	69.9%	30.1%	100.0%	
Lifetime crops grown %	(n=2922)	(n=1258)	(n=4180)	.001
0 to 2	73.1%	26.9%	100.0%	
3 to 9	71.3%	28.7%	100.0%	
More than 10	66.6%	33.4%	100.0%	
Total	69.9%	30.1%	100.0%	
Grow method %	(n=2922)	(n=1258)	(n=4180)	< .001
Soil & sunlight (S-NL)	87.6%	12.4%	100.0%	
Soil & Artificial light (S-AL)	74.5%	25.5%	100.0%	
Non-soil & Artificial light (NS-AL)	34.6%	65.4%	100.0%	
Non-soil & sunlight (NS-NL)	77.5%	22.5%	100.0%	
Total	71.0%	29.0%	100.0%	
Mainly grows outdoors %	(n=2922)	(n=1258)	(n=4180)	< .001
No	62.8%	37.2%	100.0%	
Yes	76.8%	23.2%	100.0%	
Total	69.0%	30.1%	100.0%	
Perceived legality of cannabis growing	(n=2922)	(n=1258)	(n=4180)	< .001
Prohibited	73.0%	27.0%	100.0%	
Medical only legal	70.9%	29.1%	100.0%	
Any adult use legal	59.8%	40.2%	100.0%	
Total	69.0%	30.1%	100.0%	

* Due to listwise deletion the N for this table is 4180

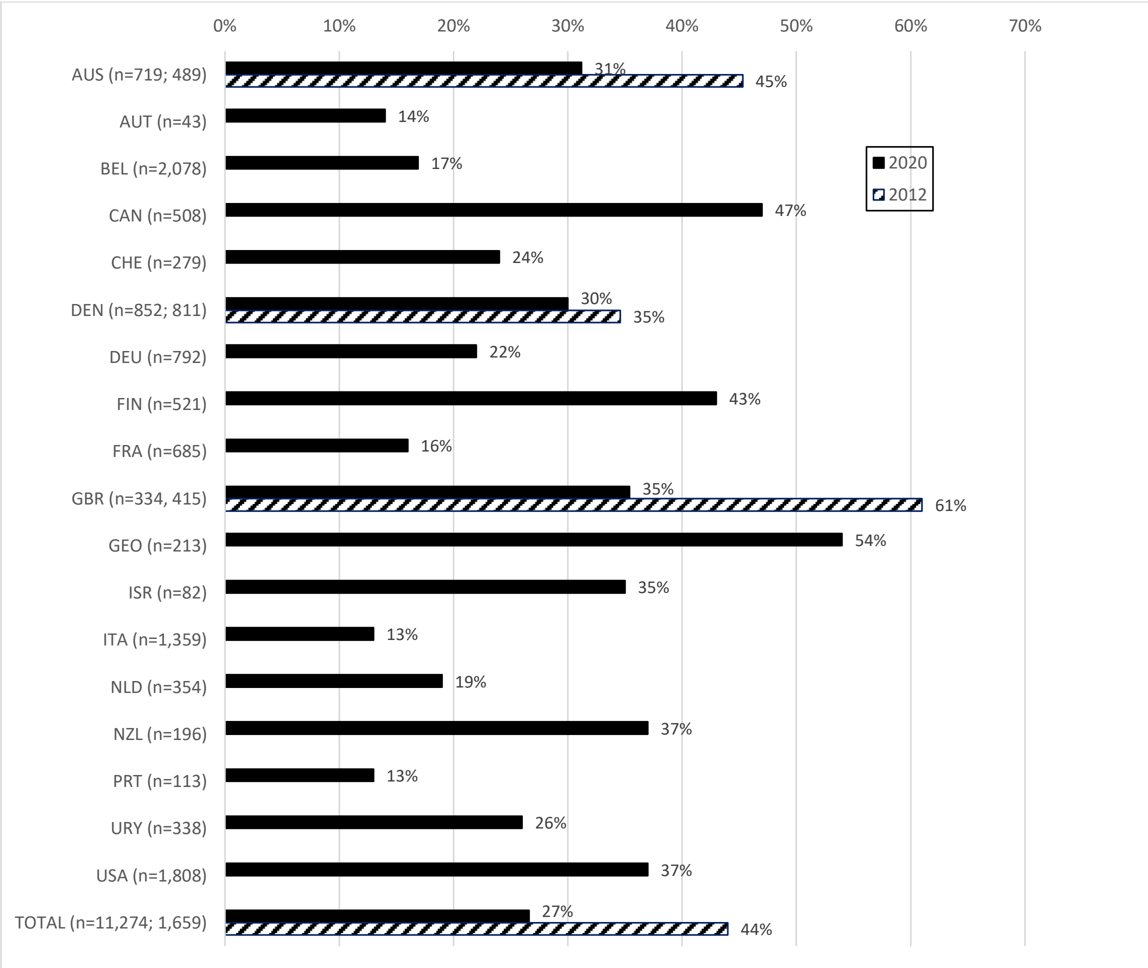
Table 6: Binomial Logistic Regression predicting use of chemical fertilizers, supplements and insecticides (N=4180)

Use of Chemicals	OR	95% CI	Sig.
Gender			
Female	1		
Male	1.496	1.262-1.773	< .001
Non-Binary	1.703	0.477-2.886	.241
Age (yrs)	1.011	1.002-1.019	.011
Employed			
No	1		
Yes	1.084	0.884-1.328	.439
Urbanicity			
Urban/City	1		
Suburban	0.842	0.738-0.960	.010
Rural	0.704	0.572-0.866	.001
Highest education level achieved			
Primary school only	1		
High school or equivalent	1.303	0.933-1.820	.120
University/college	1.397	0.970-2.011	.073
Grows for environmental reasons			
No	1		
Yes	0.692	0.604-0.793	< .001
Grow to Sell			
No	1		
Yes	1.637	1.271-2.109	< .001
Grow area			
Up to $3m^2$	1		
Over $3m^2$	0.993	0.866-1.138	.921
No. mature plants typically grow			
0-6	1		
7-10	1.042	0.839-1.292	.710
More than 10	0.965	0.759-1.228	.773
Lifetime number crops grown			
1-2	1		
3-9	0.906	0.669-1.227	.523
10 or more	0.894	0.664-1.203	.461
Grow method			
Soil & sunlight (S-NL)	1		
Soil & Artificial light (S-AL)	2.178	1.618-2.932	< .001
Non-soil & Artificial light (NS-AL)	11.205	8.382-14.980	< .001
Non-soil & sunlight (NS-NL)	2.180	0.616-7.716	.227
Grow outside			
No	1		
Yes	0.847	0.700-1.024	.087
Perceived legality of cannabis growing			
Prohibited	1		

Medical only legal	1.129	0.827-1.541	.444
Any adult use legal	1.745	1.041-2.926	.035
Constant	0.610	0.040-0.092	<.001

N.B. This analysis was clustered by Country.

Figure 1: Country by year by any chemical fertilizer use



References

Atapattu, S. N., & Johnson, K. R. D. (2020). Pesticide analysis in cannabis products. *Journal of Chromatography A, 1612*. 460656. DOI: 10.1016/j.chroma.2019.460656.

Barratt, M. J., Bouchard, M., Decorte, T., Vibeke Asmussen, F., Hakkarainen, P., Lenton, S., Malm, A., Nguyen, H., & Potter, G. R. (2012). Understanding global patterns of domestic cannabis cultivation. *Drugs and Alcohol Today, 12*,4. 213-221.

Barratt, M. J., & Lenton, S. (2015). Representativeness of online purposive sampling with Australian cannabis cultivators. *International Journal of Drug Policy, 26*,3. 323-326. DOI: http://dx.doi.org/10.1016/j.drugpo.2014.10.007.

Barratt, M. J., Potter, G. R., Wouters, M., Wilkins, C., Werse, B., Perälä, J., Pedersen, M. M., Nguyen, H., Malm, A., Lenton, S., Korf, D., Klein, A., Heyde, J., Hakkarainen, P., Frank, V. A., Decorte, T., Bouchard, M., & Blok, T. (2015). Lessons from conducting trans-national Internet-mediated participatory research with hidden populations of cannabis cultivators. *International Journal of Drug Policy, 26*,3. 238-249. DOI: http://dx.doi.org/10.1016/j.drugpo.2014.12.004.

Bengyella, L., Kuddus, M., Mukherjee, P., Fonmboh, D. J., & Kaminski, J. E. (2022). Global impact of trace non-essential heavy metal contaminants in industrial cannabis bioeconomy. *Toxin Reviews, 14*,4. 1215-1225. DOI: 10.1080/15569543.2021.1992444.

Brzozowski, L., & Mazourek, M. (2018). A sustainable agricultural future relies on the transition to organic agroecological pest management. *Sustainability (Switzerland), 10*,6. DOI: 10.3390/su10062023.

Decorte, T. (2010). Small scale domestic cannabis cultivation: An anonymous Web survey among 659 cannabis cultivators in Belgium. *Contemporary Drug Problems, 37*,2. 341-370.

Decorte, T., Lenton, S., & Wilkins, C. (2020). Legalizing Cannabis: Experiences, Lessons and Scenarios. In (1st ed., pp. 484). London: Routledge.

Decorte, T., & Potter, G. R. (2015). The globalisation of cannabis cultivation: A growing challenge. *International Journal of Drug Policy, 26*,3. 221-225. DOI: http://dx.doi.org/10.1016/j.drugpo.2014.12.011.

Drug Information and Alerts Aotearoa New Zealand (DIANZ). (2021). *High Alert: What is PGR cannabis and how do you spot it?* Available at: https://highalert.org.nz/articles/what-is-pgr-cannabis-and-how-do-you-spot-it/ [Accessed 13.06.23].

Dugar, A. (2022). *The Problems of PGR Weed & How to Spot Them*. Available at: https://greenhealthdocs.com/pgr-weed/#:~:text=The%20three%20most%20common%20synthetic,densest%20part%20of%20the%20plant. [Accessed 13.06.23]: Green Health Docs.

Dutch Passion. (2023). *Should you consider cannabis grown with PGR?* Available at: https://dutch-passion.com/de/blog/sollte-man-mit-pgr-angebautes-cannabis-in-betracht-ziehen-n1130 [Accesseed 13.06.23]: Dutch Passion.

Fiorentini, L. (2019). *Italy: Supreme Court rule on cannabis cultivation and the shame of politicians*. Fuoriluogo. Published 31 December 2019. Available at: https://www.fuoriluogo.it/globe/italy-the-decision-of-the-supreme-court-on-cannabis-cultivation-and-the-silence-of-politics/?lang=en [Accessed 08.01.24].

Fischer, B., Daldegan-Bueno, D., & Boden, J. M. (2020). Facing the option for the legalisation of cannabis use and supply in New Zealand: An overview of relevant evidence, concepts and considerations. *Drug and Alcohol Review, 39*,5. 555-567. DOI: 10.1111/dar.13087.

Giancristofaro, R. A., & Salmaso, L. (2003). Model performance analysis and model validation in logistic regression. *Statistica, 63*,2. 375-396.

Global Cannabis Cultivation Research Consortium. (2023). *International Cannabis Cultivation Questionnaire 2.0.* Available from https://worldwideweed.nl (Accessed 21.04.23).

Hakkarainen, P., Frank, V. A., Barratt, M. J., Dahl, H. V., Decorte, T., Karjalainen, K., Lenton, S., Potter, G., & Werse, B. (2015). Growing medicine: Small-scale cannabis cultivation for medical purposes in six different countries. *International Journal of Drug Policy, 26*,3. 250-256. DOI: http://dx.doi.org/10.1016/j.drugpo.2014.07.005.

Health Canada. (2017). *Clarification from Health Canada on myclobutanil and cannabis*: Health Canada. Available at; https://www.canada.ca/en/health-canada/news/2017/03/clarification_fromhealthcanadaonmyclobutanilandcannabis.html (Accessed 5.11.20).

Hermes, K. (2011). *Long-banned Alar (Daminozide) Shows Up on Hydroponic Store Shelves Before Being Removed Again*: Americans For Safe Access. Available at: http://www.safeaccessnow.org/long_banned_alar_daminozide_shows_up_on_hydroponic_store_shelves_before_being_removed_again (Accessed 13.06.16). (Archived by Webcite® at http://www.webcitation.org/6tHzkaNjf).

Integral Hydroponics. (2015). *The Curious Case of the Flower Dragon*. Available at: http://www.integralhydro.com/flower-dragon Accessed 06.07.16) Archived by WWebCite® at http://www.webcitation.org/6tI09rdw5.

Klein, A., & Potter, G. R. (2018). The three betrayals of the medical cannabis growing activist: From multiple victimhood to reconstruction, redemption and activism. *International Journal of Drug Policy, 53*. 65-72. DOI: https://doi.org/10.1016/j.drugpo.2017.12.004.

Lagrasso, J. (2021). *PGR: The Toxic Chemicals in Your Marijuana*. Available at: https://friendlyaussiebuds.com/australian-cannabis-education/pgr-toxic-weed/ [accessed 13.06.23]: Friendly Aussie Buds.

Ledger, E. (2022). *What is PGR weed? And how can you spot it?* Available at: https://www.leafie.co.uk/articles/pgr-weed-spot/ [Accessed 14.06.23]: Leafie.

Lenton, S. (2020). Regulating cannabis retail for public health over private profit. *Addiction* in press.

Lenton, S., Frank, V. A., Barratt, M. J., Potter, G. R., & Decorte, T. (2018). Growing practices and the use of potentially harmful chemical additives among a sample of small-scale cannabis growers in three countries. *Drug and Alcohol Dependence, 192*. 250-256. DOI: 10.1016/j.drugalcdep.2018.07.040.

Lenton, S., Grigg, J., Barratt, M. J., Kowalski, M., Decorte, T., Pardal, M., Martin-Milot, D., Bertrand, K., Bear, D., Asmussen-Frank, V., Friss Soegaard, T., Hakkarainen, P., Jauffret-Roustide, M., Kirtadeze, I., Werse, B., Kamphausen, G., Sznitman, S., Sotto, B., Fortin, D., Wilkins, C., Quintas Oliveira, J., Faria, R., Zobel, F., Granville, A., Potter, G., Malm, A., Sevigny, E. L., Meisel, J., Queirolo, R., Alvarez, E., & Sotto, B. (2023). *An investigation of global patterns of small-scale domestic cannabis cultivation*. Available at: osf.io/kqghe/ [accessed 09.01.24].

Li, J., Sun, L., Zuo, Z., Chen, M., Geng, H., & Wang, C. (2012). Exposure to paclobutrazol disrupts spermatogenesis in male Sebastiscus marmoratus. *Aquatic Toxicology, 122-123*. 120-124. DOI: https://doi.org/10.1016/j.aquatox.2012.06.007.

Long, J. S., & Freese, J. (2014). *Regression models for categorical dependent variables using Stata (3rd ed.)*. College Station: Stata Press.

Lu, J. (2022). *PGR cannabis: what is a plant growth regulator?* Available at: https://budherd.com.au/articles/pgr-cannabis-what-is-a-plant-growth-regulator {Accessed 13.06.23]: Bud Herd.

Manic Botanix. (undated). PGRS and Medical Marijuana. In *Manic Botanix online grow mag. Available at: https://manicbotanix.com/pgrs-and-medical-marijuana/ (Accessed 21.04.17) Archived by WWebCite® at http://www.webcitation.org/6tI1foeUf*. Available at: https://manicbotanix.com/pgrs-and-medical-marijuana/ (Accessed 21/4/17) Archived by WWebCite® at http://www.webcitation.org/6tI1foeUf.

Massachusetts Department of Agricultural Resources. (2012). *Paclobutrazol. Review Conducted by MDAR and MassDEP for Use in Sensitive Areas of Rights-of-Way in Massachusetts*. Available at: https://www.mass.gov/files/documents/2016/08/sl/paclobutrazol-review-jan-2012.pdf (Accessed 15.02.22): MDAR.

McPartland, J. M., & Pruitt, P. L. (1997). Medical marijuana and its use by the immunocompromised. *Alternative Therapies in Health and Medicine, 3*,3. 39-45.

Migoya, D. (2017). State recalls 50 Tree of Wellness medical pot products because of pesticide. *The Denver Post. Available at: https://www.denverpost.com/2017/11/03/tree-of-wellness-medical-pot-product-recall/ (Accessed 14.01.21). Archived by Perma.cc at: https://perma.cc/6JCU-696C.*

Montoya, Z., Conroy, M., Vanden Heuvel, B. D., Pauli, C. S., & Park, S. H. (2020). Cannabis Contaminants Limit Pharmacological Use of Cannabidiol. *Frontiers in Pharmacology, 11*. DOI: 10.3389/fphar.2020.571832.

National Center for Biotechnology Information. (2022). *PubChem Compound Summary for CID 15331, Daminozide.* Retrieved February 15, 2022 from https://pubchem.ncbi.nlm.nih.gov/compound/Daminozide.: NIH National Library of Medicine National Center for Biotechnology Information.

Ponisio, L. C., M'gonigle, L. K., Mace, K. C., Palomino, J., Valpine, P. D., & Kremen, C. (2015). Diversification practices reduce organic to conventional yield gap. *Proceedings of the Royal Society B: Biological Sciences, 282*,1799. DOI: 10.1098/rspb.2014.1396.

Potter, G., Barratt, M. J., Malm, A., Bouchard, M., Blok, T., Christensen, A.-S., Decorte, T., Frank, V. A., Hakkarainen, P., Klein, A., Lenton, S., Perälä, J., Werse, B., & Wouters, M. (2015). Global patterns of domestic cannabis cultivation: Sample characteristics and patterns of growing across eleven countries. *International Journal of Drug Policy, 26*,3. 226-237. DOI: http://dx.doi.org/10.1016/j.drugpo.2014.12.007.

Potter, G., & Chatwin, C. (2012). The problem with "skunk". *Drugs and Alcohol Today, 12*,4. 232-240.

Potter, G., & Klein, A. (2020). Coming out of the closet: risk management strategies of illegal cannabis growers. In S. M. a. B. Thom (Ed.), *Risk and Substance Use: Framing dangerous people and dangerous places* (pp. 201-221). London: Routledge.

Robertson, G. (2017). More than $1million of tainted medical marijuana destroyed. In *the Globe and Mail. Available at: http://www.theglobeandmail.com/news/national/morethan1millionoftaintedmedicalmarijuanadestroyed/article34026223/ (Accessed 19.04.17) [Not able to be archived due to no-cache tag]*

Singh, S. (2023). Global Cannabis Plant Nutrients Market Overview. In *Market Research Future*. Available at: https://www.marketresearchfuture.com/reports/cannabis-plant-nutrients-market-10963 [Accessed 03.11.23].

Sirius, J. (2016). What are PGR'S and why are they in my weed? In *High Times. Available at: http://hightimes.com/grow/what-are-pgrs-and-why-are-they-in-my-weed/ (Accessed 04.01.17). Archived by WWebCite® at http://www.webcitation.org/6iSayqwwH.*

Stumper, L. (2022). *What Are PGRs, and How Do They Affect Your Weed?* Available at: https://www.royalqueenseeds.com/uk/blog-what-are-pgrs-and-how-do-they-affect-your-weed-n1417 [Accessed 13.06.23]: Royal Queen Seeds.

Subritzky, T., Lenton, S., & Pettigrew, S. (2016). Legal cannabis industry adopting strategies of the tobacco industry. *Drug and Alcohol Review, 35*,5. 511-513.

Subritzky, T., Pettigrew, S., & Lenton, S. (2016). Issues in the implementation and evolution of the commercial recreational marijuana market in Colorado. *International Journal of Drug Policy, 27*. 1-12. DOI: http://dx.doi.org/10.1016/j.drugpo.2015.12.001.

Subritzky, T., Pettigrew, S., & Lenton, S. (2017). Into the void: Regulating pesticide use in Colorado's commercial cannabis markets. *International Journal of Drug Policy, 42*. 86-96. DOI: http://doi.org/10.1016/j.drugpo.2017.01.014.

Sullivan, N., Elzinga, S., & Raber, J. C. (2013). Determination of pesticide residues in cannabis smoke. *Journal of Toxicology, 2013*. DOI: 10.1155/2013/378168.

Sytar, O., Ghosh, S., Malinska, H., Zivcak, M., & Brestic, M. (2021). Physiological and molecular mechanisms of metal accumulation in hyperaccumulator plants. *Physiologia Plantarum, 173*,1. 148-166. DOI: https://doi.org/10.1111/ppl.13285.

Taylor, A., & Birkett, J. W. (2020). Pesticides in cannabis: A review of analytical and toxicological considerations. *Drug Testing and Analysis, 12*,2. 180-190. DOI: 10.1002/dta.2747.

UNODC. (2021). *World Drug Report 2021 (United Nations publication, Sales No. E.21.XI.8).* Vienna: United Nations Office on Drugs and Crime.

UNODC. (2023). *Online World Drug Report 2023 - Latest data and trend analysis*: UNODC. Available at https://www.unodc.org/unodc/en/data-and-analysis/wdr-2023-online-segment.html (Accessed 14.07.23).

Venhuis, B. J., & van de Nobelen, S. (2015). *Cannabis contaminants*. Bilthoven. : Rijksinstituut voor Volksgezondheid en Milieu. Available at: https://www.eerstekamer.nl/overig/20160120/rivm_rapport_cannabis/document (accessed 20.06.17).

Voelker, R., & Holmes., M. (2015). *Pesticide use on cannabis*. Available at: https://cdn.technologynetworks.com/tn/Resources/pdf/pesticide-use-on-cannabis.pdf (Accessed 16.11.20): Cannabis Safety Institute.

Weedhack Staff writer. (2023). *The dangers of PGR cannabis & how to identify it*. Available at: https://weedhack.de/pgr-cannabis-duenger-gefahren-identifizieren/ [Accessed 13.06.23]: Weedhack.

Xu, M., & Yang, F. (2020). Integrated gender-related effects of profenofos and paclobutrazol on neurotransmitters in mouse. *Ecotoxicology and Environmental Safety, 190*. DOI: 10.1016/j.ecoenv.2019.110085.