

ARTICLE | Full-text available
Current and Future Needs and Applications for Cannabis
February 2017 - Critical Reviews in Plant Sciences 35(5-6):1-2 - Follow Journal
DOI: 10.1080/07352689.2017.1284529
Projects: Cannabis genetic variation - Crit. Rev. Plant Sci. Special Issue on Cannabis - Genomic Review in Cannabis Sativa
Dennis J. Gray · Haillie Baker · Kayla Clancy · Show all 24 authors · Robert N. Trigiano

Presented by BGI Genomics
A Practical Guide to RNA Data Analysis and Visualization Approaches for Publication Ready Results
Online event Sponsored
Agenda
Learn more about RNA analysis and get a practical introduction to common data visualization approaches, software tools and challenges, covering: Expression Analysis, Gene Set Enrichment Analysis, Association Analysis, Referencing Ontological Information Across Multiple Databases, and Data Mining
View event
Event speakers
Dr Yuxin Sun
Data Analysis Project Manager - BGI G...

Abstract
Add an abstract
Let other researchers know what your work is about

C.J., increase the visibility of this article
If your co-authors confirm their authorship, more researchers will find and read this article on ResearchGate.
Kayla Clancy
Kirsten Müller-Vahl
J. Paul Mendieta
Travis C. Ruthenberg
Haillie Baker
Invite co-authors Not now

Related research
Compromised External Validity: Federally Produced Cannabis Does Not Reflect Legal Markets
Preprint File available October 2016
Download
View more

Public Full-text Private Full-text
Content uploaded by C.J. Schwartz Author content
Content may be subject to copyright.

gray\_et al\_3-1-2017\_Current an.pdf
Page 1



Current and Future Needs and Applications for Cannabis

Dennis J. Gray, Haillie Baker, Kayla Clancy, Robert C. Clarke, Kymron deCesare, John Fike, Matthew J. Gibbs, Franjo Grotenhermen, Nolan C. Kane, Kyle G. Keepers, Donald P. Land, Ryan C. Lynch, J. Paul Mendieta, Mark Merlin, Kirsten Müller-Vahl, Christopher S. Paull, Brian J. Pearson, Bailey Rhan, Travis C. Ruthenberg, C. J. Schwartz, Silas B. Tittes, Daniela Vergara, Kristin H. White & Robert N. Trigiano

To cite this article: Dennis J. Gray, Haillie Baker, Kayla Clancy, Robert C. Clarke, Kymron deCesare, John Fike, Matthew J. Gibbs, Franjo Grotenhermen, Nolan C. Kane, Kyle G. Keepers, Donald P. Land, Ryan C. Lynch, J. Paul Mendieta, Mark Merlin, Kirsten Müller-Vahl, Christopher S. Paull, Brian J. Pearson, Bailey Rhan, Travis C. Ruthenberg, C. J. Schwartz, Silas B. Tittes, Daniela Vergara, Kristin H. White & Robert N. Trigiano (2017): Current and Future Needs and Applications for Cannabis, Critical Reviews in Plant Sciences, DOI: 10.1080/07352689.2017.1284529
To link to this article: http://dx.doi.org/10.1080/07352689.2017.1284529

Published online: 26 Feb 2017. Submit your article to this journal
Article views: 11. View related articles
View Crossmark data

Full Terms & Conditions of access and use can be found at
http://www.tandfonline.com/action/journalInformation?journalCode=bpts20
Download by: [University of Colorado at Boulder Libraries] Date: 01 March 2017, At: 16:29

Page 2

CRITICAL REVIEWS IN PLANT SCIENCES
http://dx.doi.org/10.1080/07352689.2017.1284529
Taylor & Francis

Current and Future Needs and Applications for Cannabis

Dennis J. Gray<sup>a</sup>, Haillie Baker<sup>b</sup>, Kayla Clancy<sup>b</sup>, Robert C. Clarke<sup>c</sup>, Kymron deCesare<sup>d</sup>, John Fike<sup>e</sup>, Matthew J. Gibbs<sup>f</sup>, Franjo Grotenhermen<sup>g</sup>, Nolan C. Kane<sup>h</sup>, Kyle G. Keepers<sup>i</sup>, Donald P. Land<sup>j</sup>, Ryan C. Lynch<sup>k</sup>, J. Paul Mendieta<sup>l</sup>, Mark Merlin<sup>m</sup>, Kirsten Müller-Vahl<sup>n</sup>, Christopher S. Paull<sup>o</sup>, Brian J. Pearson<sup>p</sup>, Bailey Rhan<sup>q</sup>, Travis C. Ruthenberg<sup>r</sup>, C. J. Schwartz<sup>s</sup>, Silas B. Tittes<sup>t</sup>, Daniela Vergara<sup>u</sup>, Kristin H. White<sup>v</sup>, and Robert N. Trigiano<sup>w</sup>

<sup>a</sup>Mid-Florida Research and Education Center, University of Florida, Apopka, Florida, USA; <sup>b</sup>Department of Ecology and Evolutionary Biology, University of Colorado, Boulder, Colorado, USA; <sup>c</sup>BioAgromics Group Consultants, Los Angeles, California, USA; <sup>d</sup>Steep Hill Labs Inc, Berkeley, California, USA; <sup>e</sup>Medicinal Genomics Corporation, Woburn, Massachusetts, USA; <sup>f</sup>Department of Botany, University of Hawaii, Honolulu, Hawaii, USA; <sup>g</sup>Link for Psychiatry, Sozialpsychiatrie und Psychotherapie, Medizinische Hochschule, Hannover, Germany; <sup>h</sup>Leafly.com, Seattle, Washington, USA; <sup>i</sup>Marigene Inc., Fort Collins, Colorado, USA; <sup>j</sup>SC Laboratories Inc., Seattle, Washington, USA; <sup>k</sup>Entomology and Plant Pathology, University of Tennessee, Knoxville, Tennessee, USA

I. Introduction
With the resurgence of interest in cannabis, for fiber, oil, and drug uses, we now can realistically look forward to consider future needs required to establish it as a modern crop. With the anticipation of future funding opportunities, it is likely that many avenues for its further domestication will become available. Here, we have asked the experts featured in this Special Issue to provide their thoughts and recommendations.

There remains some confusion in the taxonomy of the genus Cannabis. At present, we consider drug and hemp varieties to be a single species, Cannabis sativa L. with three subspecies - indica, sativa, and ruderalis. However, a different diagnosis of species contained in the genus is discussed in some chapters, as mentioned in the definitions section of this Special Issue. This emphasizes the need to further study the relatedness among members of the genus Cannabis. Efforts outlined in the works of Lynch and colleagues (this issue) and Vergara and colleagues (this issue), with future investigations to understand the genome(s) of cannabis, will certainly elucidate these relationships.

II. Crop management and production
As discussed by Rahn and colleagues (this issue), both the drug and hemp cannabis industries are rapidly moving forward to become legitimized as they once were, but the industries currently do not have best management practices in place for production and processing. For example, there are no accepted standards for pesticide usage nor whether products contain safe levels of

residues. Similarly, there are no requirements to certify the identities of the varieties in production (Rahn et al., this issue). For the industry to become legitimized and accepted, such crucial standards must become established. There now is, and increasingly will be, a call to arms for scientific research to answer driving questions about the crop. These needs are urgent due to the current rapid expansion of the industry.

III. Crop improvement
The absence of basic resources such as public germplasm collections still hinders the improvement and development of cultivars, and crop improvement specialists will require creative and collaborative solutions to overcome many problems arising from decades of scientific neglect. Concurrent with the loosening of restrictions for cannabis worldwide and the expansion of both medicinal and social use, a switch from small-scale clandestine cultivation to large-scale commercial agriculture is underway. As with all other crops, the vast majority of production will most likely come from a handful of cultivars. On the other hand, as has happened with coffee, craft beer and fine wine, there likely will be opportunities for small producers to market products made from a wide range of varieties. This will drive the quest to breed more interesting "trademark" cultivars with distinct appearances, flavor profiles, and effects.

Genetic improvement of cannabis grown under the broad definition of hemp will likely influence an increasing need for plant breeding and agronomic research. Hemp, by international convention and legal definition, must contain less than 0.3% THC by dry weight. Planting non-hemp drug varieties in regions allowing

CONTACT Dennis J. Gray djd@ufl.edu Mid-Florida Research and Education Center, University of Florida/IFAS, 2725 S. Binion Road, Apopka, FL 32703, USA
© 2017 Taylor & Francis

Page 3

2 D. J. GRAY ET AL.

industrial hemp cultivation to produce CBD makes the legal maximum limit of 0.3% THC content difficult to manage. When CBDA content is increased through breeding and improved cultivation techniques, a small quantity of THCA is always observed, which trends toward the legal limit. This problem already has led to significant crop loss. During 2016, about half of nearly 5,000 acres of cannabis planted in Colorado for CBDA production was lost because it tested over the legal THC limit (personal information).

Although traditional breeding will offer solutions to this and other issues, newly-available gene editing tools will provide new ways to fine-tune traits.

IV. Medical cannabis
We expect two major developments in the future medical use of cannabis: one concerning the use of cannabinoid-derived medicinal drugs in general, and the other concerning new sociopolitical-related cannabis policies developing around the world.

New medical treatments with cannabis, cannabinoid, and other modulators of the endocannabinoid system will likely make their way into the clinics and medical practice in the future, including the following:

- 1. Agents that increase the concentration of endocannabinoids by the inhibition of the enzymes responsible for their degradation, including inhibitors of fatty acid amino hydrolase, which results in an increased concentration of anandamide.
2. Agents that only bind to one of the cannabis receptors, mainly the CB2 receptor, whose activation does not cause psychological effects in contrast to the activation of the CB1 receptor.
3. Agents that bind to CB1 receptors, but do not penetrate the brain, will avoid psychotropic effects.
4. New endocannabinoid receptors will come into scientific focus, including vanilloid receptors and endocannabinoids, of which we are just beginning to investigate.
5. Basic investigations into the mechanisms of action of cannabinoids that affect the endocannabinoid system will give researchers insights into understanding the modulation of regulatory systems in much greater depth.

Socially and politically, medicinal use of cannabis is increasingly being accepted by governments of countries across North America, South America, and Europe. It is likely that acceptance of cannabis will continue to increase around the world in the years ahead. The scientific research community already has confirmed the low risk of adverse effects. Because a number of significant medical benefits conferred by cannabis and cannabinoids are becoming increasingly better known and accepted, people around the world should no longer be denied access to such age-old treatments.

There already has been almost 50 years of modern medical research into cannabis and cannabinoids. Clearly, the next half century will not be less exciting!

V. Looking forward
The prospects of creating genetically modified microorganisms that produce cannabinoids, rather than relying on actual cannabis plants, are attractive. One can imagine future production occurring in the highly controlled environment of liquid-based bioreactors located in secure production facilities. By identifying and recovering active DNA sequences from cannabis and then inserting them into certain microorganisms that can successfully translate them into pure drugs, production can be brought into an industrial setting. Strains of genetically modified yeast that produce cannabinoids already have been created, but yields currently are too low to be useful. Ongoing research on yeast seeks to increase yields of target cannabinoids to an economically acceptable level.

VI. Conclusion
It is very interesting to see one of humanity's most valued, ancient domesticated crops, which was long ignored in recent times, to become the subject of such increased scientific, social, and economic interest. The purpose of this Special Issue on Cannabis was to bring forward and update information within a proper scientific venue and to serve as a foundational reference source for future research on the crop. To address and begin to correct such a lapse in the literature base was an opportunity that the authors could not resist.

Similar research
Compromised External Validity: Federally Produced Cannabis Does Not Reflect Legal Markets
Preprint File available October 2016
Daniela Vergara · L. Cinnamon Bidwell · Reggie Gaudino · [...] · Nolan Coburn Kane
As the most widely used illicit drug, the basis of the fastest growing major industry in the US, and as a source of numerous under-studied psychoactive compounds, understanding the psychological and physiological effects of Cannabis is essential...
5 Reads · 2 Citations
Download Recommend Follow Share

Foreword to the Special Issue on Cannabis
Article Full-text available November 2016 - Critical Reviews in Plant Sciences
Dennis J. Gray · Robert N. Trigiano
40 Reads
Download Recommend Follow Share

The complete chloroplast genomes of Cannabis sativa and Humulus lupulus
Article Full-text available September 2015 - Mitochondrial DNA
Daniela Vergara · Kristin H. White · Kyle Keepers · Nolan Coburn Kane
Cannabis and Humulus are sister genera comprising the entirety of the Cannabaceae sensu stricto, including C. sativa L. (marijuana, hemp), and H. lupulus L. (hops) as two economically important crops. These two plants have been used by humans for man...
1,016 Reads · 20 Citations
Download Recommend Follow Share

Genomic and Chemical Diversity in Cannabis
Article Full-text available December 2015
Ryan C Lynch · Kristin H. White · Kristin White H.
Phenolics of the Cannabis genus are the producers of phytochemicals, terpenoid compounds that strongly interact with evolutionarily ancient endocannabinoid receptors shared by most bilaterian taxa. For millennia, the plant has been cultivated...
628 Reads · 15 Citations
Download Recommend Follow Share

The complete mitochondrial genome for Cannabis sativa
Article Full-text available January 2016 - Mitochondrial DNA Part B
Kristin H. White · Daniela Vergara · Kyle Keepers · Nolan Coburn Kane
The following report details the first annotated mitochondrial genome for the Carmagnola variety of Cannabis sativa, the first reference genome for the Cannabaceae family. The total length is 415,499 bp and contains 54 genes, which su...
192 Reads · 10 Citations
Download Recommend Follow Share

View more related research