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# Bibliometric and Scientometric Analysis of Scopus-Indexed Literature on Hemp (*Cannabis sativa*) Breeding

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***Authors' contributions***

*This work was carried out in collaboration among all authors. Author NN designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors LB, CM, NM and TM managed the analyses of the study and the literature searches. Authors NN and LB wrote the final copy of the draft. All authors read and approved the final manuscript.*

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## ABSTRACT

The elevated research interest and increased cultivation of Hemp (*Cannabis sativa*) across the globe is significantly driven by its multidirectional industrial uses and medicinal properties. Scientific research publications focusing on hemp breeding plays a pivotal role in bridging the knowledge gap and opening new avenues for upscaling the efficiency of crop improvement initiatives. The identification of prevailing research trends and associations is critical in defining and mapping the trajectories of success in Hemp breeding. The advent of bibliometrics and scientometrics is currently providing a stead platform which fosters effective identification of current research patterns and examination of the applied methodologies, focus areas, and operational constraints. In the context of Hemp research, content assessments provide breeding initiatives with background data needed for exploring various traits of interest and for validating

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investments and related policies. The main thrust of this study is to perform a bibliometric and scientometric analysis of Scopus-indexed papers covering the field of 'Hemp Breeding', between calendar years 1908 and 2020. Data was analyzed using VOSviewer (Version 1.6.16) and Microsoft Excel (2019). The study found 152 papers composed of original articles (105, 69.08%), book chapters (23, 15.13%), conference papers (10, 6.58%), reviews (9, 5.92%), conference reviews (3, 1.97%) and books (2, 1.32%). A significant increment in research publications was observed after 1950. The assessment also indicated that most of the archived research was conducted or reported in the USA (13.82%), Italy (12.5%) and the Netherlands (11.18%). Furthermore, the highest number of papers over the studied period and topic were published by authors affiliated to Wageningen University & Research (16, 10.53%). Index keywords such as *Cannabis sativa,* hemp, genetic expression, genetic marker, and genetic diversity were covered extensively in the sampled journal editions. A comparative assessment of the results indicated that there is need to scale-up research initiatives targeting hemp trait improvements to cater for the projected high demand and climate change. This can be achieved through strengthening synergistic partnerships and knowledge exchanges across the hemp breeding value chain. This research will assist plant breeders in defining research requirements, determining evidence-based scientific gaps, and recognizing outstanding research institutions for potential intellectual sharing and cooperation.

*Keywords: Bibliometrics; content assessments; hemp; scientometrics; scopus-indexed papers.*

## 1. INTRODUCTION

Hemp (*Cannabis sativa*) is an herbaceous plant that is currently receiving increased attention from researchers and policymakers owing to its industrial use (in production of textiles, biofuel, and bioplastics) and medicinal properties. This triggers an urgent need to produce varieties that are suited to the requirements of emerging developments in the use of hemp by the concerned industries [1]. Research systems should therefore complement and support growers to ensure sustainability in hemp cropping schemes that are currently threatened by the adverse effects of climatic variabilities and the COVID-19 pandemic.

The current breeding landscape continues to witness numerous milestones in novel varietal releases and cultivar improvement. However, crop productivity gains have plateaued over the years owing to a wide array of abiotic and biotic stresses [2,3]. The current advances in plant breeding technologies can provide a powerful tool in the fight against the adverse effects of these stresses on agricultural productivity [4,5]. However, plant breeding initiatives aimed at improving hemp genotypes have been at a record low over the last decades. The prioritization of hemp breeding systems can help in countering several limitations that hinder the advancement of plant biology knowledge and enable full domestication and maximization of the agronomic potential of this promising crop [6].

The drive to counter the negative effects of these challenges inspired several scholars to embark on breeding research initiatives targeting agronomic trait improvement [7,8,9], yield [10,11], nitrogen use efficiency [12,13], disease [14,15,16,17], drought [18] and cold [19] tolerance in various plants including hemp. The archived research literature plays a crucial role in bridging the knowledge gap and in promoting the efficient dissemination of latest research outputs to the wide global audience in various fields of plant sciences. Particularly, peer-reviewed scientific journals continue to relay value-laden knowledge and provide quality benchmarks for effective communication in scientific research.

Bibliometric and scientometric analyses of the published research papers provide a summarized overview of the latest trends and pinpoint fields that require particulate attention in the future. The concept of these analyses has been applied and utilized extensively in various fields and more effectively in social sciences. The adoption of such methodologies equips plant breeders with the necessary tools for examining current research trends and modelling future hemp breeding profiles. Furthermore, the assessment of hemp literature is paramount in laying sustainable foundations for building efficient and resilient breeding schemes. This study fulfils this need by gathering and examining the content of high-impact scientific papers archived in the Scopus Database. The research aims to assess the existing patterns in hemp breeding research by defining research topics,

trends, and associations. The evidence gathered in this exercise can be employed in identifying the relevant parties (or stakeholders), encouraging collaboration, and building platforms for future studies in the field of cannabis breeding.

## 2. RESEARCH METHODOLOGY

### 2.1 Introduction to Bibliometrics and Scientometrics

Bibliometric analysis is a statistical and mathematical technique used to analyze data from peer-reviewed journal articles, books, conference proceedings, periodicals, reviews, reports, and related documents [20,21]. The term was first coined by Pritchard in 1969 [22] as a technique to measure, assess, compare, and rank publications, trace relationships and identify research trends [23]. Bibliometrics can be employed extensively in qualitative and quantitative research methodologies for analyzing the contents, references, citations, and authorship of publications.

Scientometrics is a subfield of the bibliometrics' scientific domain which involves the quantification and evaluation of the impacts of science, technology, and innovations and the use of such measurements in policy and governance processes [24]. Scientometric endeavours to estimate the impact of publications and their authors in influencing knowledge development. Furthermore, it provides an insight into the impact of scientific citations as a medium for scholarly communication, mapping of intellectual landscapes and production of focus indicators as used in the assessment of research performance and productivity [25].

### 2.2 Data Collection

A bibliometric and scientometric analysis was conducted on 152 open access and peer-reviewed papers published between the year 1908 and 2020 in Scopus-indexed Journals (presented in Table 1). Scopus is an abstract and citation database that was established in 2004 by Elsevier Science Limited. Identification of the articles was achieved in November 2020 (Access Date: 15.11.2020) through direct searches in the Scopus Database (https://www.scopus.com). The articles were extracted from a 'Hemp Breeding' search query output. The study included all document types (152) published within the targeted timescales (1908 – 2020).

### 2.3 Data Analysis

The collected data was exported to Microsoft Excel (2019) and VOSviewer (Version 1.6.16 (https://www.vosviewer.com/)) for statistical analysis and data visualization as per the study objective. Co-authorship and co-occurrence analyses were conducted using the counting method on VOSviewer (Version 1.6.16). Descriptive statistics (i.e. Frequencies and Percentages) were calculated using Microsoft Excel (2019) and utilized as the major basis for assessment.

**Table 1. The Studied Scopus-Indexed Journals**

| Journal | Articles | Journal 2 | Articles |
|---|---|---|---|
| Industrial Crops and Products | 15 | International Journal of Molecular Sciences | 1 |
| Euphytica | 9 | Iop Conference Series Earth and Environmental Science | 1 |
| Frontiers in Plant Science | 7 | Journal of Agricultural Meteorology | 1 |
| Journal of Industrial Hemp | 7 | Journal of Applied Animal Research | 1 |
| Journal of Natural Fibers | 7 | Journal of Applied Microbiology | 1 |
| Bulletin on Narcotics | 3 | Journal of Ecological Engineering | 1 |
| Journal of Heredity | 3 | Journal of Economic Entomology | 1 |
| Plos One | 3 | Journal of Environmental Science and Health Part B Pesticides Food Contaminants and Agricultural Wastes | 1 |
| Biotechnology and Biotechnological Equipment | 2 | Journal of Forensic Sciences | 1 |
| Crop Science | 2 | Journal of Small Animal Practice | 1 |
| Inform International News on Fats Oils and Related Materials | 2 | Lijecnicki Vjesnik | 1 |

| Journal | Articles | Journal 2 | Articles |
|---|---|---|---|
| Acta Agronomica Hungarica | 1 | Molecular Breeding | 1 |
| Acta Facultatis Xylologiae | 1 | Molecular Ecology | 1 |
| Advanced Materials Research | 1 | Molecules | 1 |
| Agricultural and Forest Meteorology | 1 | New Phytologist | 1 |
| Agronomy | 1 | Novenytermeles | 1 |
| Aob Plants | 1 | OCL Oilseeds and Fats | 1 |
| Applications in Plant Sciences | 1 | OCL Oilseeds and Fats Crops and Lipids | 1 |
| Biotechnology Letters | 1 | Ornithologische Beobachter | 1 |
| Cannabis and Cannabinoid Research | 1 | Phytochemistry Reviews | 1 |
| Carbohydrate Polymers | 1 | Plant and Soil | 1 |
| Caryologia | 1 | Plant Breeding | 1 |
| Clean Soil Air Water | 1 | Proceedings on Applied Botany Genetics and Breeding | 1 |
| Critical Reviews in Plant Sciences | 1 | Review of Palaeobotany and Palynology | 1 |
| Crop Protection | 1 | Sel Skokhozyaistvennaya Biologiya | 1 |
| Economic Botany | 1 | Shengtai Xuebao Acta Ecologica Sinica | 1 |
| European Journal of Plant Pathology | 1 | Southern African Forestry Journal | 1 |
| Fibres And Polymers | 1 | Sugar Tech | 1 |
| Field Crops Research | 1 | TUT Textiles A Usages Techniques | 1 |
| Frontiers in Genetics | 1 | Talanta | 1 |
| Gcb Bioenergy | 1 | Theoretical and Applied Genetics | 1 |
| Genes | 1 | Trends in Biotechnology | 1 |
| Genes and Genomics | 1 | Tsitologiia I Genetika | 1 |
| Genetic Resources and Crop Evolution | 1 | Turkish Journal of Botany | 1 |
| Genetika | 1 | Vitamins and Hormones | 1 |
| Genome Biology | 1 | Water Research | 1 |
| Herba Polonica | 1 | Weed Research | 1 |

## 3. RESULTS AND DISCUSSION

### 3.1 Analysis of Publications

The study found 152 papers composed of original articles (105, 69.08%), book chapters (23, 15.13%), conference papers (10, 6.58%), reviews (9, 5.92%), conference reviews (3, 1.97%) and books (2, 1.32%) as shown in Fig. 1. The observed statistics shows that this area of study is still at a preliminary level. The limited number of hemp research schemes and cultivar release platforms can be attributed to the low number of publicly available germplasm [26]. Conservation of the available genetic resources and application of genomics-oriented systems in hemp breeding is, therefore, a necessity.

The number of published papers according to years is shown in Fig. 2. The graph shows that publications on hemp were constant at one published paper per year since 1908. A continuous increment in the numbers of publications was later observed starting from 1950. A second upward trend was recorded after 1992 with frequent fluctuations in the years that followed. The increased publication intensities can be attributed to the growing appreciation of the medicinal uses of hemp amongst the general populace and the growth of industrial streams which absorbs large quantities of hemp as a raw material for textile, biofuels, and bioplastics. However, the observed increments in publications are mainly concerned with the broader aspects related to hemp cultivation which are not conclusively linked to hemp genetics [27] or breeding.

### 3.2 Analysis of Journal Contributions

A total of 33 journals were identified as contributors to hemp breeding content on the Scopus Database. Fig. 3. presents the observed number of published papers per journal. The highest number of published papers were observed in the Industrial Crops and Products,

Frontiers of Plant Science and Journal of Natural Fibres. Despite these developments, published work on forensic genetics are still limited [27]. Moreover, the current scientific archives show that there is a lack of review studies reporting on the overall research trends of hemp [27]. Bibliometric and scientometric analyses should therefore be out-scaled to cover other online databases for accurate and reliable assessments of the current status of scientific and academic literature on hemp breeding.

### 3.3 Analysis of Country Contributions

A total of 35 countries contributed to the sampled data frame (Fig. 4). The results revealed that most of the hemp breeding studies were done in the USA (13.82%) followed by Italy (12.5%) and the Netherlands (11.18%). The legalization of medicinal marijuana in 11 states of the USA can be the main reason for its dominance in hemp research. Europe and Africa had the highest and lowest representation, respectively. The dominance of these developed countries in plant breeding research can be attributed to the high financial investments being channelled towards scientific research schemes. However, it is important to note that country contributions can overestimate or underestimate research work involving collaborating institutions [27] across the territorial divide. In some cases, the affiliation may not be a reliable indicator of the exact origin of the published paper. South Africa was the only African country with documented research work included in the sampled data. The study also classified 10 papers as undefined since these covered research studies conducted by several research initiatives across the globe.

### 3.4 Analysis of Author Contributions

A total of 420 authors contributed to the sampled data set of published papers. Ranalli P, Trindade L.M and de Meijer E. P. M contributed the highest number of papers (n = 6 papers each). Fig. 5. shows the names of authors with more than three articles in the sampled data frame.

### 3.5 Citation Analysis

Citation frequencies report is presented in Table 2. The citation analysis showed that the highly cited papers reported on work done in Italy (897) followed by the Netherlands (477) and Canada (350). The highest number of citations was achieved by Amaducci, S. (297) and Ranalli P (297). The high citation frequencies are an indicator of the impact and quality of the research work published by these authors on hemp. High-quality papers with innovative methodologies and credible experimental results are cited on a variety of occasions [28].

Author association analysis (Fig. 6) produced a network map with circles of different thicknesses (or proportional frequencies) and connecting lines indicating author collaboration link intensities. The analysis also confirms the high contribution of the aforementioned authors in hemp breeding research.

### 3.6 Analysis of Author Affiliations

A total of 263 institutions contributed to the sampled data set of published papers. Fig. 7. shows the most prolific research institutions in hemp research. The Wageningen University & Research (WUR) was ranked in the pole position in Hemp breeding (16, 10.53%) over the studied period. WUR is a top-ranked research and academic institution in the Netherlands. The institute is mostly popular in spearheading state-of-art research in the fields of biological sciences.

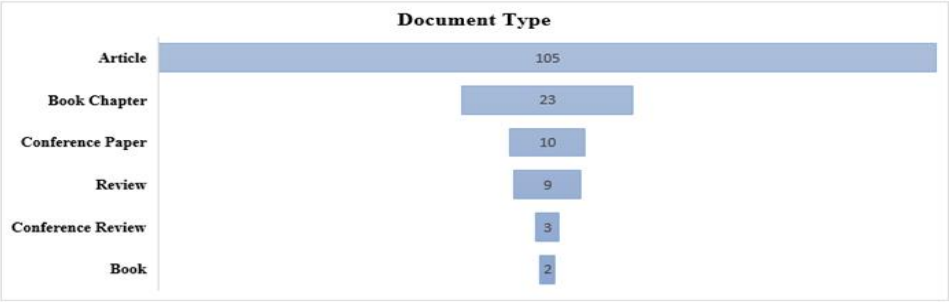


**Fig. 1. Types of published papers covering Hemp breeding between 1908 and 2020**

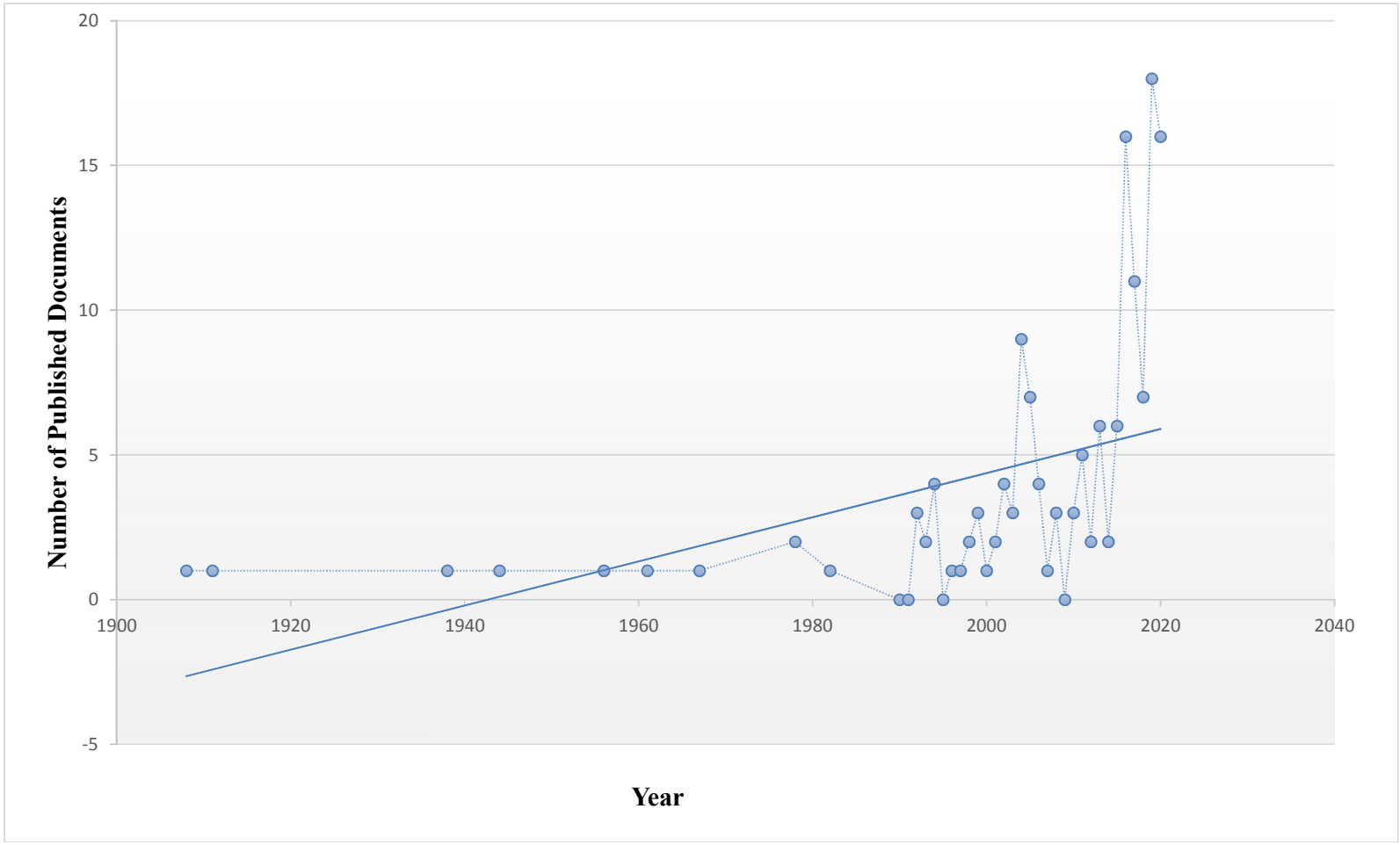


**Fig. 2. Historical profile on the number of publications**

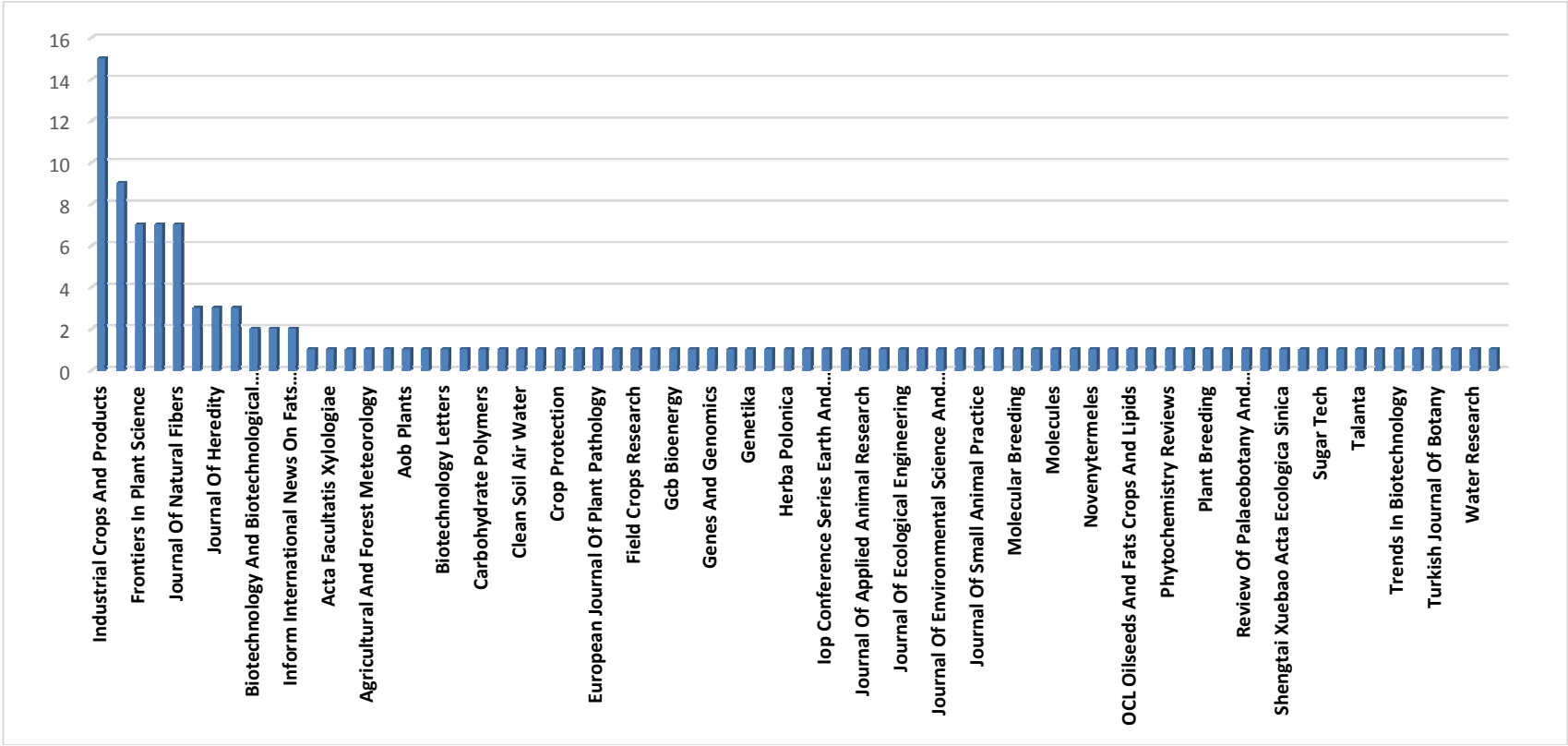


**Fig. 3. Number of published papers according to the name of the scientific journal**

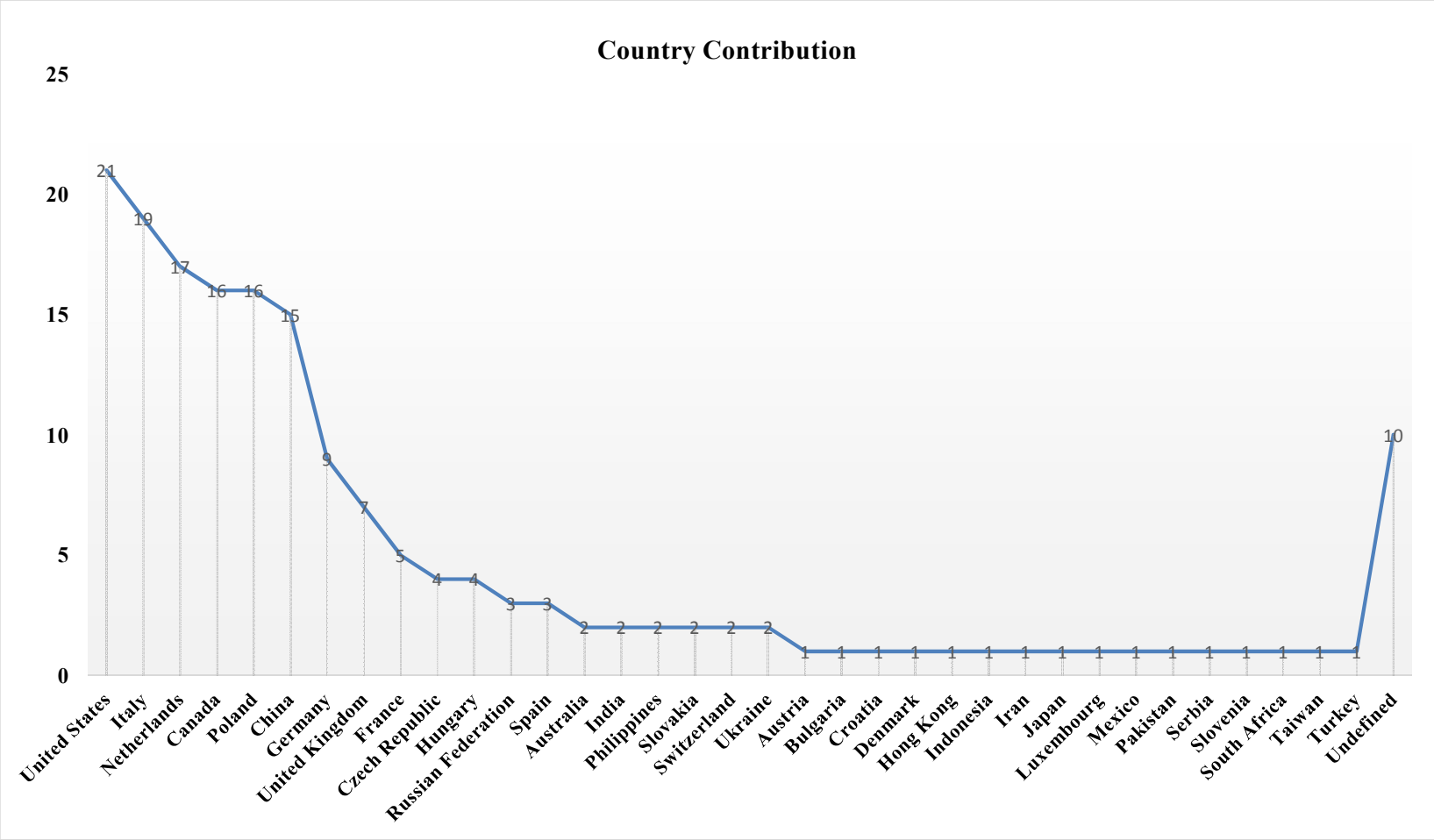


**Fig. 4. Research Article classification based on the countries where the study was conducted**

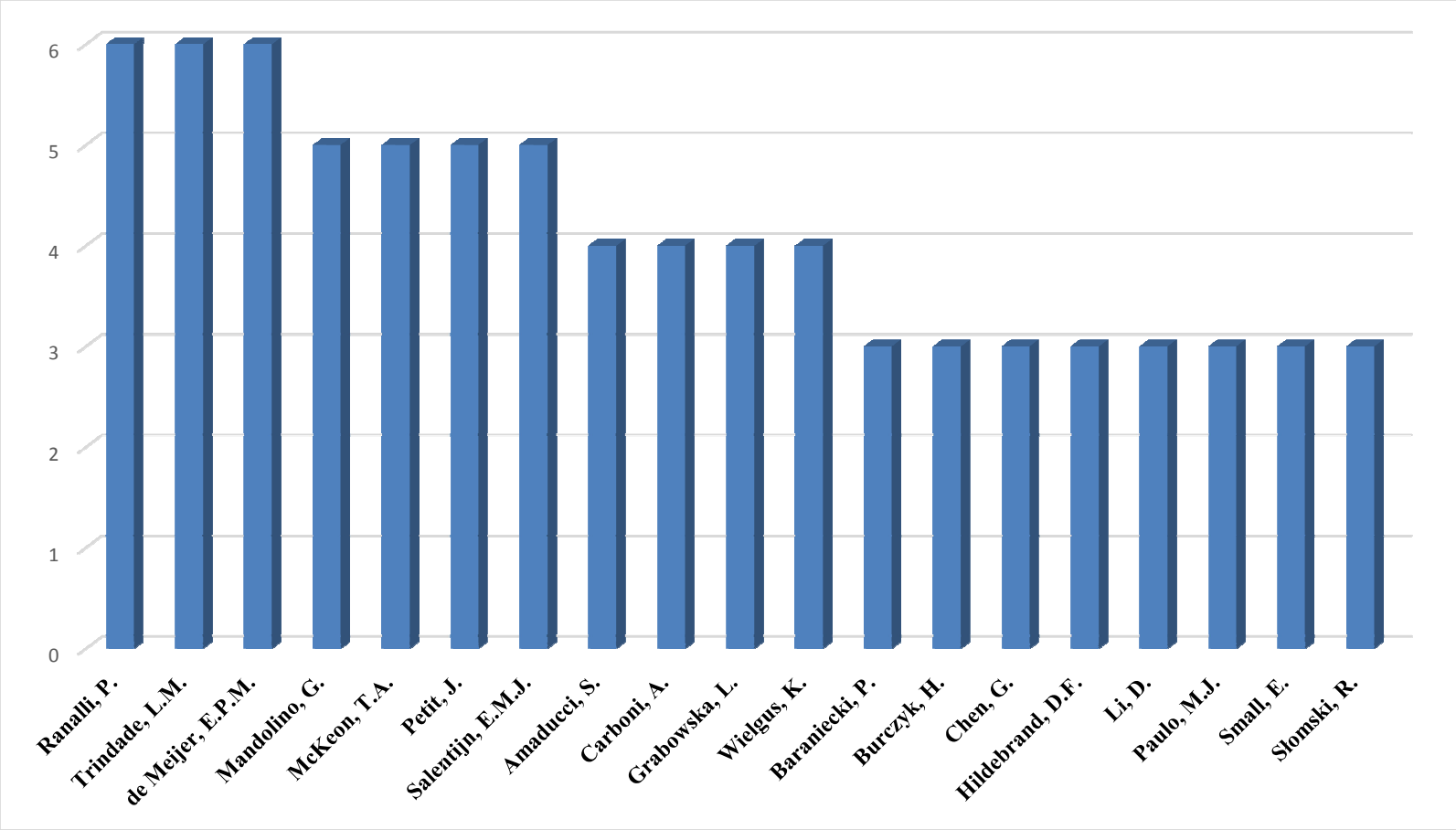


**Fig. 5. Authors with more than three papers**

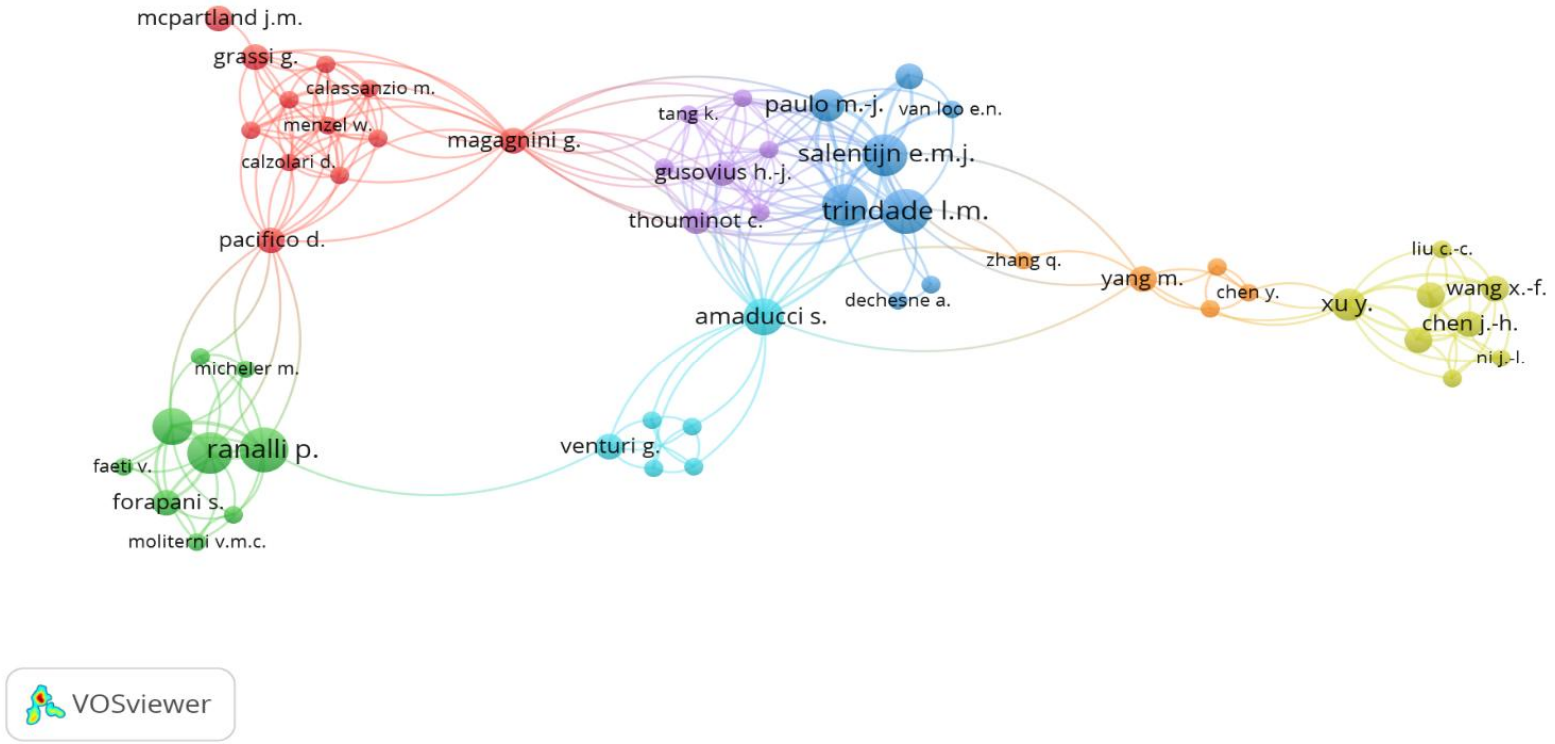


**Fig. 6. Joint mapping of author associations**

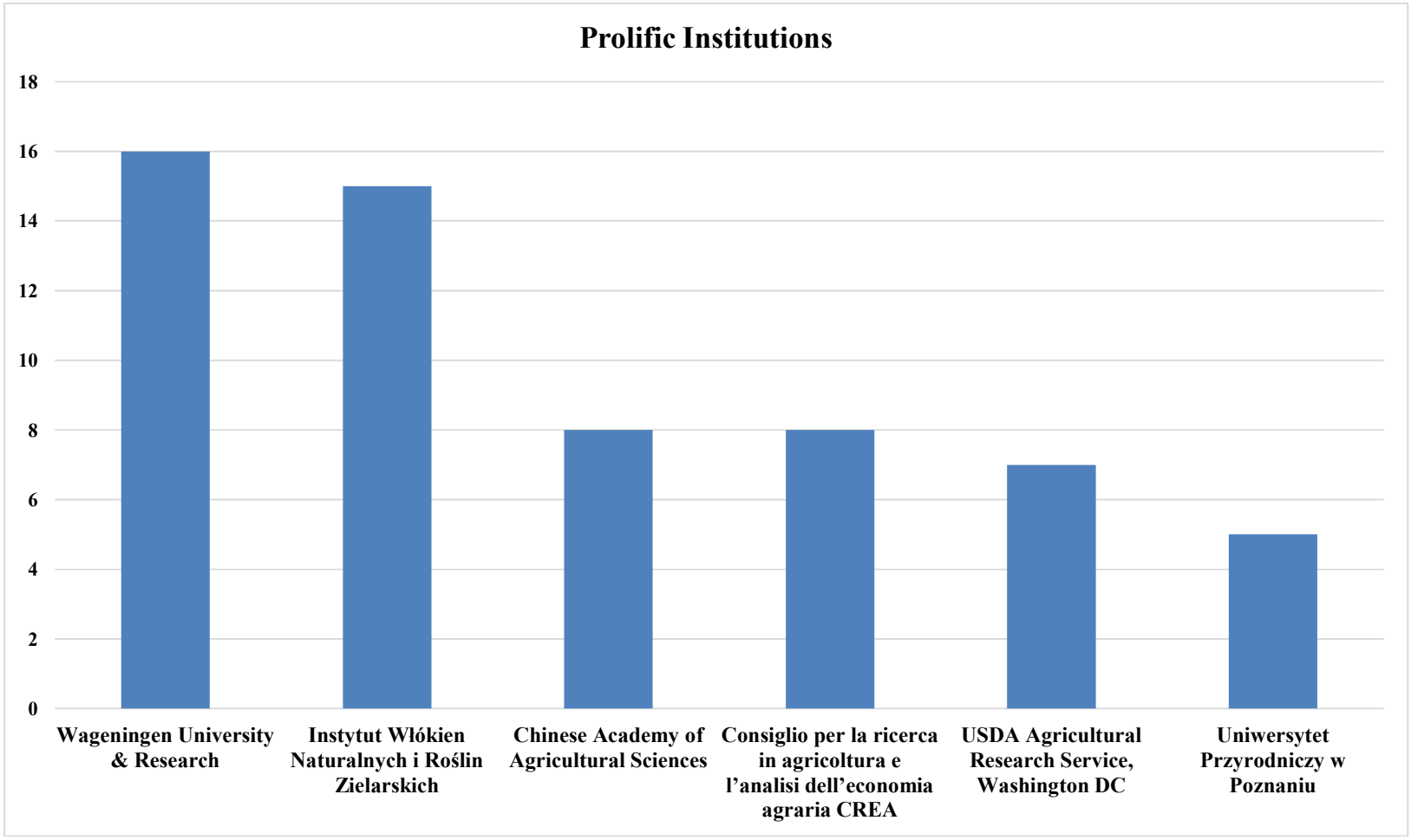


**Fig. 7. Prolific research institutions**

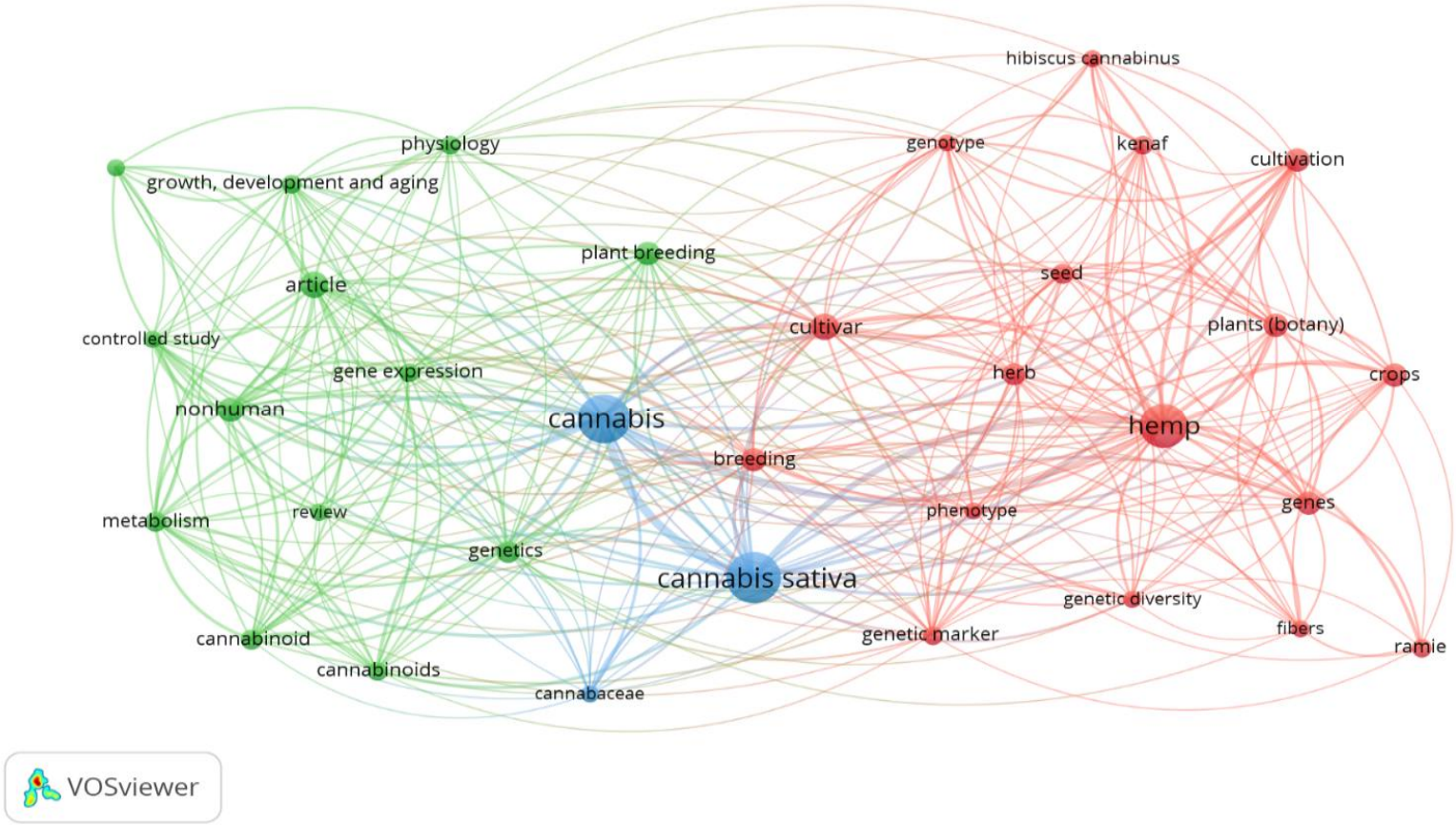


**Fig. 8. Co-occurrence mapping of keywords**

**Table 2. Authors with the highest number of citations**

| Rank | Author | Documents | Citations |
|---|---|---|---|
| 1 | Amaducci S | 4 | 297 |
| 2 | Ranalli P. | 6 | 297 |
| 3 | Cote A.G. | 1 | 253 |
| 4 | Hughes T.R. | 1 | 253 |
| 5 | Page J.E. | 1 | 253 |
| 6 | Sharpe A.G. | 1 | 253 |
| 7 | Stout J.M. | 1 | 253 |
| 8 | Tallon C.M. | 1 | 253 |
| 9 | van Bakel H. | 1 | 253 |
| 10 | Venturi G. | 2 | 242 |

### 3.7 Analysis of the Co-occurrence Keywords

The study identified a total of 966 keywords that were used in the sampled articles. A network analysis was conducted on the 33 co-occurrence keywords (i.e. keywords that were repeated on five or more occasions). The sampled data showed a wider diversity in terms of the research focus as illustrated by the keyword network map shown in Fig. 8.

The circles and lines shown as nodes on the map denote different thicknesses (or proportional frequencies) and collaboration link intensities. The most commonly used index keywords were 'Cannabis', Cannabis sativa', 'Hemp' and 'Cultivar'. The sampled papers also reported on research themes such as genetic diversity [29-33], fibre quality [34,35], pollen quantification and sex genetics [36,37], cannabinoid content [38], seed oil [39] and pulp yield [40].

## 4. CONCLUSION

The present research sought to conduct a bibliometric and scientometric analysis of Scopus-indexed papers and determine the current research trends and future opportunities in hemp breeding. The study discovered 152 papers consisting of articles, book chapters, conference proceedings, reviews, and books. The limited number of research papers is a clear indication of the existing knowledge gap in the field of hemp breeding. The research trends in the studied journals showed that genetic diversity, genetic resource conservation and improvement of agronomic traits were taking a center stage in the hemp breeding landscape. The assessment also indicated that the USA, Italy, and the Netherlands were the most productive countries in hemp breeding. Furthermore, over the studied period (1908 - 2020) and subject area (i.e., Hemp Breeding), WUR published the highest number of papers on the Scopus Database. Conclusively, the provided information can be used by public and private research entities in identifying key stakeholders, promoting cooperation and creating platforms for further research in hemp breeding.

## DISCLAIMER

The products used for this research are commonly and predominantly used products in our area of research and country. There is no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by the personal efforts of the authors.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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