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A century of common bean: bibliometrics and scientific production

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ABSTRACT

This pioneering study applied bibliometric techniques and indicators to investigate more than a century of scientific production on common bean (*Phaseolus vulgaris* L.). This food item has the greatest global representation for cultivation and consumption, and it produces a significant impact on the nutritional quality of many populations. We analyzed over 15,000 scientific publications indexed in the Scopus database. The historical perspective based on indicators of diffusion, collaboration, and impact made it possible to map the main countries and lines of research on common bean. Our results indicate the predominance of studies on productivity, genetic improvement, nutritional quality, disease resistance, and adaptation to different cultivation environments. These research topics are associated with the evolutionary and domestication processes of this legume. Moreover, countries like the United States (the leading country), Brazil, United Kingdom, Canada, Spain, Mexico, Colombia, and India stand out. Institutional arrangements, associated with scientific and technological projects of global scope, management structure, and conservation of genetic resources put the United States and other nations under the scientific spotlight for common bean research.

Index terms: impact assessment, *Phaseolus vulgaris*, scientific production.

Ideias centrais

- Análise de indicadores de difusão, colaboração e impacto científico de 15 mil publicações sobre feijoeiro comum.
- Predominância de estudos sobre produtividade, melhoramento genético, qualidade nutricional, resistência a doenças e adaptação a diferentes ambientes de cultivo.
- Tópicos de pesquisa estão associados aos processos evolutivos e de domesticação do feijoeiro comum.
- Estados Unidos, Brasil, Reino Unido, Canadá, Espanha, México, Colômbia e Índia se destacam na produção científica.

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Um século de feijão-comum: bibliometria e produção científica

RESUMO

Este é um estudo pioneiro que utilizou técnicas e indicadores bibliométricos para investigar mais de um século de produção científica sobre o feijoeiro-comum (*Phaseolus vulgaris L.*), alimento com maior representatividade em cultivo e consumo no mundo e de significativo impacto na qualidade nutricional de muitas populações. Foram analisadas cerca de 15 mil publicações científicas indexadas na base de dados Scopus. A perspectiva histórica, baseada em indicadores de difusão, colaboração e impacto, permitiu mapear os principais países e linhas de pesquisa. Os resultados indicam a predominância de estudos sobre produtividade, melhoramento genético, qualidade nutricional, resistência a doenças e adaptação a diferentes ambientes de cultivo. Esses tópicos de pesquisa estão associados aos processos evolutivos e de domesticação dessa leguminosa. Além disso, destacam-se países como Estados Unidos, Brasil, Reino Unido, Canadá, Espanha, México, Colômbia e Índia. Desse conjunto, os Estados Unidos são os protagonistas. Arranjos institucionais, associados a projetos científicos e tecnológicos de âmbito global, estrutura de gerenciamento e conservação de recursos genéticos, colocam os EUA e outras nações no centro das atenções científicas quanto à pesquisa do feijão-comum.

Termos para indexação: *Phaseolus vulgaris*, avaliação de impacto, produção científica.

INTRODUCTION

Research impact assessment (RIA) has become even more prominent because of its importance in providing knowledge and information for measuring research support investments, for its socio-economic value, and for accountability (Penfield et al., 2014; Morton, 2015). In this respect, RIA studies are relevant for sustaining the work of players in competitive, resource-limited environments, as is the case of science, technology, and innovation (STI) systems (Georghiou & Roessner, 2000; Weißhuhn et al., 2018; Williams & Grant, 2018).

Considering the diversity of agents that act in the STI environment, RIA can take on different scopes of analyses, such as academic, organizational (programs, policies, and institutions), and sectorial performances, among others. The definition of RIA models is related to the aim of the assessment, to the environment in which the object of study is found, and to the expected results (Moed & Halevi, 2015; Joly & Matt, 2017). In this respect, multidimensional RIAs are based on combinations of appropriate indicators for the different scopes and dimensions of analyses. Bibliometrics, by its turn, is a prominent methodological approach within this scientific impact assessment (Durieux & Gevenois, 2010; Moed & Halevi, 2015). Thus, bibliometric indicators are used to measure the quantity and quality of scientific production, to evaluate areas of knowledge and specific themes. With this in mind, we mapped the scientific production and knowledge dissemination related to common bean (*Phaseolus vulgaris* L.), using bibliometric techniques.

Bean is a seed of a leguminous plant of the *Phaseolus* genus. The main species grown throughout the world are *Phaseolus vulgaris* L., *P. lunatus* L., *P. coccineus* L., *P. acutifolius* var. *latifolius* G.F.Freeman, and *P. polyanthus* Greenm. (Singh et al., 1991). The most cultivated species of bean, as well as the most consumed in the world is *Phaseolus vulgaris* L., also known as common bean (Chiorato et al., 2018). This legume is largely grown as a grain crop (dry beans) or as a fresh vegetable (green beans). It acts as the foundation to food security for various populations around the world, due to its low cost of production, smaller impact on the family budget, and recognized nutritional quality (Hayat et al., 2014; Hartmann & Siegrist, 2017). Furthermore, grain legumes are also important for the sustainability of agrofood systems (Magrini et al., 2019). Hence, dry grains of common bean (*Phaseolus vulgaris L.*) play a prominent role in this context.

The biggest producers of dry beans are Myanmar (which produced almost 6 million tonnes in 2019[9]), India (around 5 million tonnes), and Brazil (approximately 3 million tonnes), followed by China, United Republic of Tanzania, Uganda, United States of America, Mexico and Kenya (FAO, 2019).

[9] The reference period is the harvest year.

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Common bean (CB) accounts for a high proportion of daily protein intake in many regions, particularly in Latin America, Africa, and parts of Asia. Beans are also an economically significant food legume and vegetable crop in Canada, United States of America, and Europe (Assefa et al., 2019). Its consumption is particularly high in African countries — for instance, per capita consumption ranges from 50 kg to 60 kg per year in Rwanda, Kenya, and Uganda (Broughton et al., 2003; Buruchara et al., 2011). Common bean is also very rich in nutrients, with both protein and complex carbohydrates, vitamins (such as A, C, folate), dietary fiber, and biologically important minerals, such as Ca, Mg, K, Cu, Fe, Mg, and Zn (Broughton et al., 2003; Blair et al., 2013).

The originality of this research stems from the lack of studies regarding global scientific production on common bean. There are few studies on beans when compared to other relevant species, and a bibliometric approach could contribute to systematize data on the field (Kafer et al., 2021). Thus, this is the first longitudinal study using bibliometric techniques to investigate more than a century of scientific production about the bean crop (from 1903 to 2019). What the literature does provide are few, overarching bibliometric studies in agriculture, with specific themes related to plant species. They mostly emphasize soy (Magrini et al., 2019) and other products, such as rice (Morooka et al., 2014), coffee (Cruz-O'Byrne et al., 2020), maize (Yuan & Sun, 2020), and citrus (Souza et al., 2013). Furthermore, these studies rely on localized databases and can also be divided among different scopes of analysis, such as shorter timeframes, geographic regions, and impact indicators (citations, collaboration and scientific networks, and scientific journal pro files) (Cañas-Guerrero et al., 2013; Oliveira et al., 2017; Irizaga & Vanz, 2021).

The studies nearest our own are those which applied bibliometric techniques within the bean research field. Miyamoto et al. (2017) characterized the scientific production regarding bean golden mosaic, one of the main viral diseases which attack common bean fields in Brazil. Rajendran (2021) used the CAB Direct database, in order to conduct an overview of research on the theme from 2011 to 2013. Kafer et al. (2021) applied scientometric approaches regarding the application of molecular markers in genetic studies on CB. Spatti et al. (2021) employed bibliometric techniques to measure the internationalization of Brazilian research within CB research topic. Our research complements these works by broadening the spectrum of scientific evaluation surrounding CB research globally because it offers a historical perspective and recovery data from Scopus, which is one of the most recognized international scientific database.

The results discussed in this article are part of an RIA on CB led by a public research organization in Brazil.

METHODOLOGY

We applied bibliometric techniques and indicators to the analysis of scientific publications to identify the evolution, dissemination, and impact of research outputs related to CB. Bibliometrics, as a statistical-mathematical instrument for the measurement of indices of scientific production (Araújo, 2006), allows of the evaluation of scientific and technological performances at researcher, institution, and geographical levels, with the support of metrics such as the number of citations, coauthorship networks, institutions, keywords, etc. (Okubo, 1997). Bibliometrics is a tool that assists the researcher in the systematization of scientific and technological information, as well as in the mapping and generation of different information management indicators (Guedes & Borschiver, 2005).

To characterize scientific publications related to CB, we considered the terms "*Phaseolus vulgaris*", "common bean", and "dry bean" within the following Boolean search query (Table 1). The term "dry bean" was inserted in the query with the aim to align the search results with the scope of the research program that is the object of our RIA.

Table 1. Boolean search query regarding common bean.

TITLE-ABS-KEY("Phaseolus vulgaris" OR "common bean*" OR "dry bean*")

We chose Scopus (Elsevier) as the bibliographical information database. This choice is based on the scope and volume of Scopus (Brazilian and international) and by its multidisciplinary character (Archambault et al., 2009). Furthermore, it is a database of abstracts and citations of scientific literature and of academic level information sources that indexes more than 22,000 scientific journals from 5,000 international publishers, as well as other types of documents (Elsevier, 2015).

In order to capture the scientific trajectory of the theme, the first year of bibliographic production analysis was defined by the date of the first document found by the Boolean query, in this case, 1903. To define the final year of the timeframe, we ignored the most recent years of the series, as recommended by Costa et al. (2019), due to the probability that these publications had not yet been completely indexed to Scopus and, for that reason, would be subject to underestimation. Thus, the timeframe used in this research was from 1903 to 2019.

The Boolean search query was applied to Scopus on January 26, 2021, and it showed the predominance of the "Agricultural and Biological Sciences" and "Biochemistry, Genetics, and Molecular Biology" knowledge areas, which represent around 75% of all scientific production regarding CB for the selected timeframe. The other areas are the following: Medicine (5%); Environmental Science (5%); Immunology and Microbiology (4%); Chemistry (3%); Neuroscience (3%); Nursing (2%), Pharmacology, Toxicology, and Pharmaceutics (1%); and Engineering (1%); and the rest was distributed among Multidisciplinary areas, Chemical Engineering, Veterinary, Earth and Planetary Sciences, Social Sciences, Materials Science, Energy, Physics and Astronomy, Computer Science, and Health Professions.

Since "Agricultural and Biological Sciences" and "Biochemistry, Genetics, and Molecular Biology" are the most representative areas, we have chosen to analyze only research outputs regarding CB published within these areas of knowledge. Our total set contained 15,349 documents including articles published in scientific journals, conference papers, books, and book chapters. For the analyses of data, and the systematization of the information and exploratory analyses, we used the MS Excel and QGis softwares. *VOSViewer* was also utilized for the mapping of the bibliometric information networks.

RESULTS AND DISCUSSION

This study used bibliometric metrics to investigate more than a century of scientific production on CB. Our results showed that over 95% of the 15,349 scientific publications regarding CB are research papers, for which "Agricultural and Biological Sciences" accounted for 52% of the documents, and "Biochemistry, Genetics, and Molecular Biology", for 28%.

The historical trajectory of CB (Figure 1) shows that the first article was published in 1903 and presented experimental results regarding nutrient uptake by the CB crop (Von Portheim, 1903). The largest number of scientific production outputs (627 publications) was in 2017. Positive growth of around six publications per year worldwide is a notable trend.

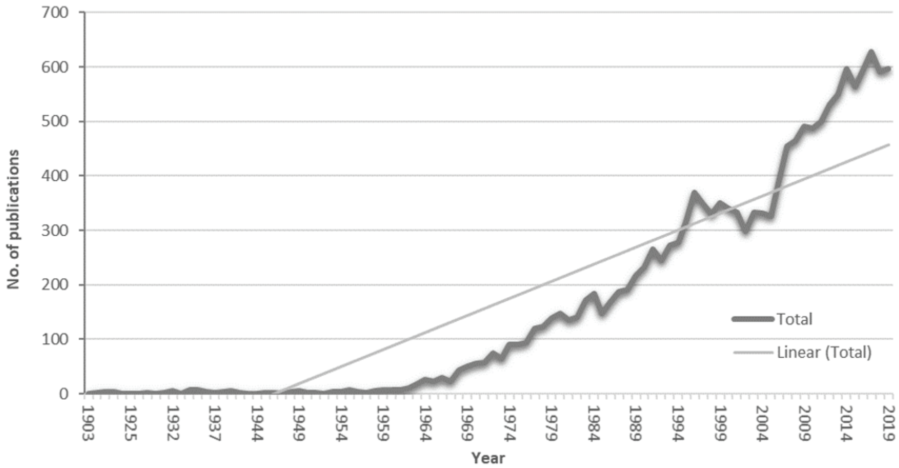

Figure 1. Distribution of scientific production regarding common bean, 1903-2019. The publications include articles published in scientific journals, conference papers, books, and book chapters.

As to country participation (Figure 2), the United States plays a central role (24% of all research output). They are followed by Brazil (17%), the United Kingdom (7%), Canada (6%), Mexico (5%), and India (5%), which also figure as key disseminators of knowledge. Some of the largest producers and consumers of beans also stand out as major scientific producers (this is the case of Brazil, India, Mexico, and USA). However, this is not a rule, since the economic importance of CB for Canada, USA, and Europe contributes to this scenario (Assefa et al., 2019). According to Kafer et al. (2021), the remarkable participation of the USA may be related to its financial and scientific structure, which ends up attracting researchers and funding. Magrini et al. (2019) also showed the prominence of the USA and countries on the European continent in the scientific production of soybean and pulses, and these authors highlight that the legume bean is among the five main species studied, contributing 10% of scientific production.

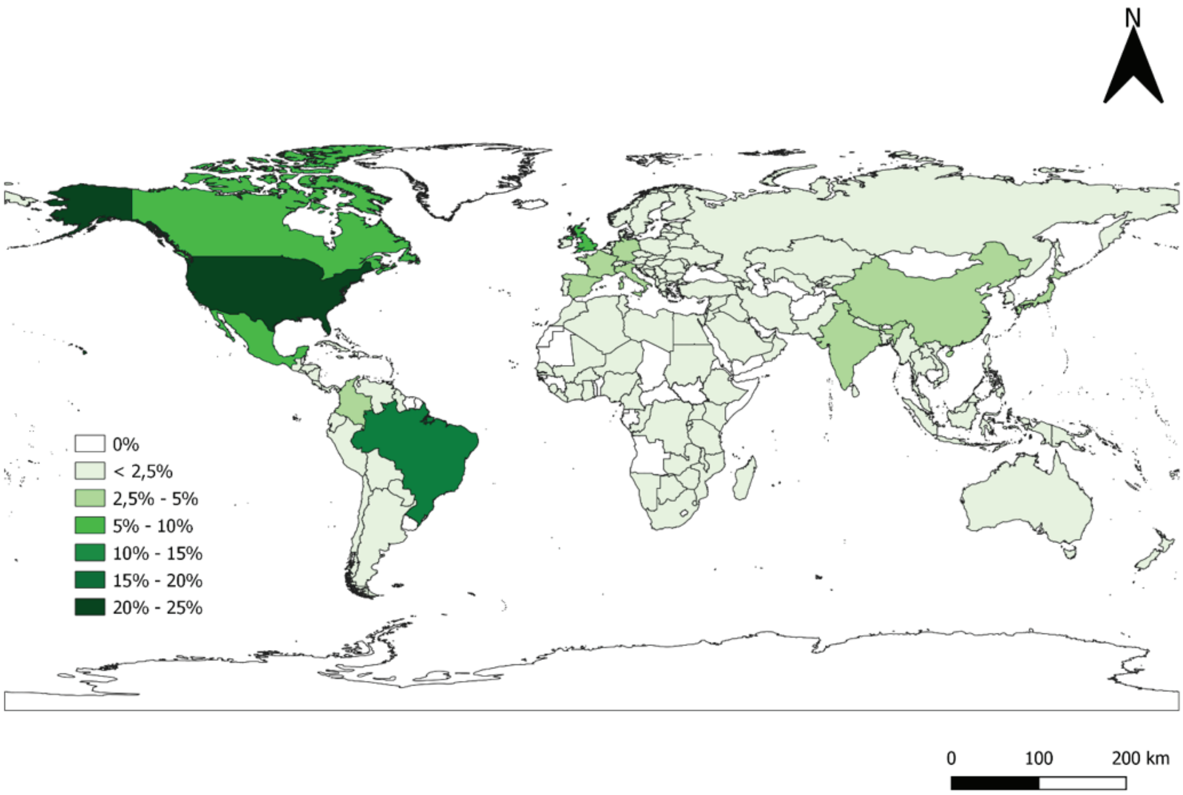

Figure 2. Map of country participation in scientific production regarding common bean (%), 1903-2019.

These results are complemented by information on the international coauthorship networks established in the country of the institution to which the authors are affiliated (Figure 3). According to Miyamoto et al. (2017), a scientific coauthorship network is a social network, in which two authors (vertices) are considered "connected" if they have written an article together. In the map, the size of the sphere is proportional to the number of publications of the country. Thus, the larger the sphere, the greater the scientific output of that country. The connections, in turn, represent coauthorship relationships. The more intense this connection, measured by the thickness of the line, the larger the number of combined studies among researchers of those countries.

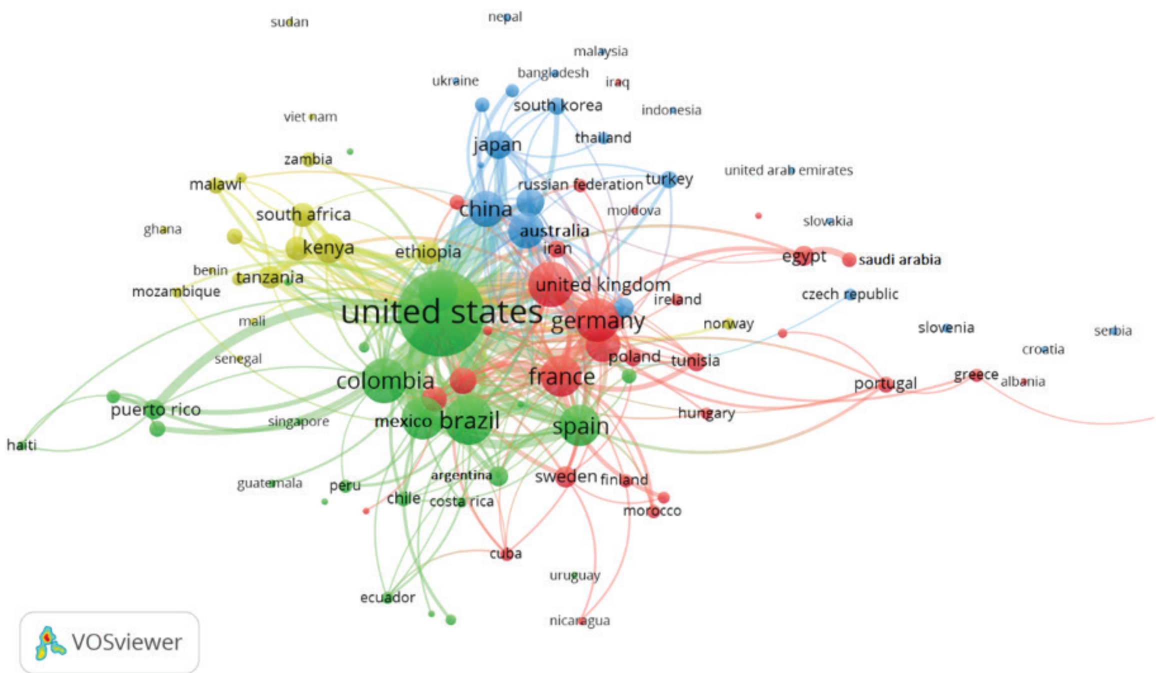

Figure 3. Scientific production regarding common bean: collaboration network among countries, 1903-2019. Note: The network was constructed based on the countries of institutional affiliation of coauthors in publications regarding common bean in the Scopus database. Different colors represent different clusters of collaboration. The size of the sphere that represents the country is based on the number of publications. The connecting lines indicate the 100 strongest co-occurrence connections among the countries with at least 5 publications.

This network confirms the representativeness of the USA, Brazil, France, Spain, Germany, Mexico, and Colombia for the overall number of publications. Furthermore, it shows the strong relationship between Brazil and the USA, and the centrality of the USA within the coauthorship network. The USA prominence in collaboration networks between countries was also observed in a bibliometric study on the scientific outputs of soybean and other legumes (pulses) in the period 1980–2018 (Magrini et al., 2019), in a study on CB scientific internationalization (Spatti et al., 2021), and in an article on the impact of molecular markers in CB (Kafer et al., 2021).

The consolidation of four coauthorship clusters, illustrated by the colors green, red, blue, and yellow are also presented (Figure 3). The green cluster (Brazil, United States, Spain, Mexico, Chile, Colombia, and Peru, among others) indicates prominence both in number of publications and the intensity of the established coauthorship relationships (which also involves various Latin American countries). The red cluster (France, Italy, Germany, the United Kingdom, Portugal, Egypt, Iran, etc.) has weaker relationships than the green cluster, but still includes a considerable number of publications. The blue cluster (China, India, Australia, Turkey, Japan, etc.), by its turn, shows comparatively fewer publications on CB, and the coauthorship relationships predominantly occur around the United States. Finally, the yellow cluster (Kenya, South Africa, Tanzania, Ethiopia, etc.) consists of moderate indicators of coauthorship and overall research output.

The results shown (Figures 2 and 3) may be related to the maintenance of genetic resource collections in referenced research centers of different countries. As it can be seen, countries with important collections of genetic accesses stand out both in citation and country collaboration networks, such as USA, Colombia, Germany, Brazil, Spain, etc. This fact indicates that the maintenance of collections of genetic resources and the sharing of genetic accesses result in collaborative scientific outputs and strengthened networks.

The global collections of genetic resources and germplasms can be characterized in various ways: by genotype (that is, marker- or sequence-based characterization), by phenotype (such as growth habit, seed characteristics, disease responses, photoperiod response, etc.), by pedigree, genepool, race, or by geographic origin. The world's largest germplasm collections of CB are maintained in the following institutions and countries: at the Food and Agriculture Organization (FAO), under the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), at the International Center for Tropical Agriculture (CIAT) in Cali, Colombia (around 36,000 accessions), with a backup at the Svalbard Global Seed Vault in Norway, where more than 50,000 accessions are now held; at the U.S. Department of Agriculture (USDA), in Pullman, Washington, USA (about 15,000 accessions); at the Institute für Pflanzengenetik und Kulturpflanzenforschung (IPK), Germany (about 9,000 accessions); in Brasília, Brazil (Brazilian Agricultural Research Corporation, Embrapa Genetic Resources & Biotechnology, with about 6,000 accessions); in Beijing, China (CAAS, Institute of Genetic Resources with more than 5,000 accessions); and at the National Center for Plant Genetic Resources in Alcalá de Henares, Spain (with more than 5,000 bean accessions) (Assefa et al., 2019).

In addition to the germplasm collections, databases are important initiatives to promote the production and dissemination of knowledge. Therefore, substantial phenotype data is maintained in the USA, in the Germplasm Resources Information Network (GRIN) web server, which provides germplasm information from the USDA's National Genetic Resources Program (NGRP). Other important initiatives of research are the USA Bean Coordinated Agricultural Project (BeanCAP) and Pan-Africa Bean Research Alliance (PABRA) supported by a consortium formed by CIAT and donors (Buruchara et al., 2011; Moghaddam et al., 2014).

A different representation highlights the citation network among countries (Figure 4). Colors are based on the mean normalized citation scale (number of citations of each publication divided by the total number of citations of the universe). The size of the sphere represents the number of normalized citations received (number of citations of the country divided by the mean number of citations of all documents published in the same year). Normalization corrects the fact that older documents have taken longer time to receive citations than more recent documents.

The citation network shows that not only the United States has the largest number of documents on the theme, as above mentioned, but also it is the country whose publications have the largest number of normalized citations (sphere size), and the largest mean number of citations (see normalized scale) (Figure 4). Thus, we can infer that the USA has the largest impact in citations on common bean research – 1.4 impact, which means 40% more citations than the mean. A similar situation is observed for countries represented in yellow (Colombia, Australia, Germany, the United Kingdom, Belgium, and China), with a mean of normalized citations from 1.2 to 1.4. Mexico, Canada, and Portugal are highlighted in green, with a moderate mean number of citations (1.0, precisely the mean number of citations, to 1.2), and, in blue, are countries with a low mean number of citations (Brazil, India, Iran), ranging from 0.6 (40% fewer citations than the mean) to 0.8.

The combined analysis of the participation of countries in scientific production (Figure 2), and of the collaboration networks and citations among countries (Figures 3 and 4) indicates the predominant role of the USA as a key player in the scientific production and dissemination regarding common bean. The strong representation of the USA favors the countries it collaborates with as for the number of citations. Our results corroborate those by Spatti et al. (2021) for the analysis of the field-weighted citation impact of the CB scientific outputs, which shows that publications in international collaboration are most cited than the global average.

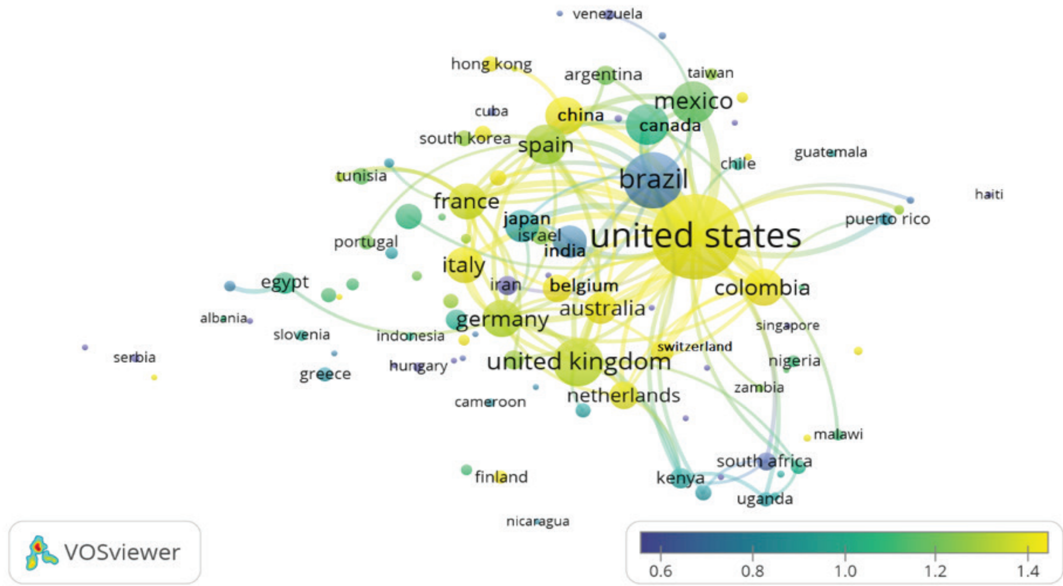

Figure 4. Scientific production regarding common bean: citation network among countries, 1903-2019. Note: the network was constructed with basis on the countries of institutional affiliation of co-authorships in publications regarding common bean, in the Scopus database. Colors are based on the mean normalized citation scale (number of citations of each publication divided by the total number of citations of the universe). The size of the sphere is based on the number of normalized citations received (number of citations of the country divided by the mean number of citations of all documents published in the same year). The connecting lines indicate the 100 strongest co-occurrence connections among the countries with at least 5 publications.

The map of keywords indicated by authors in publications regarding common bean is shown in Figure 5.

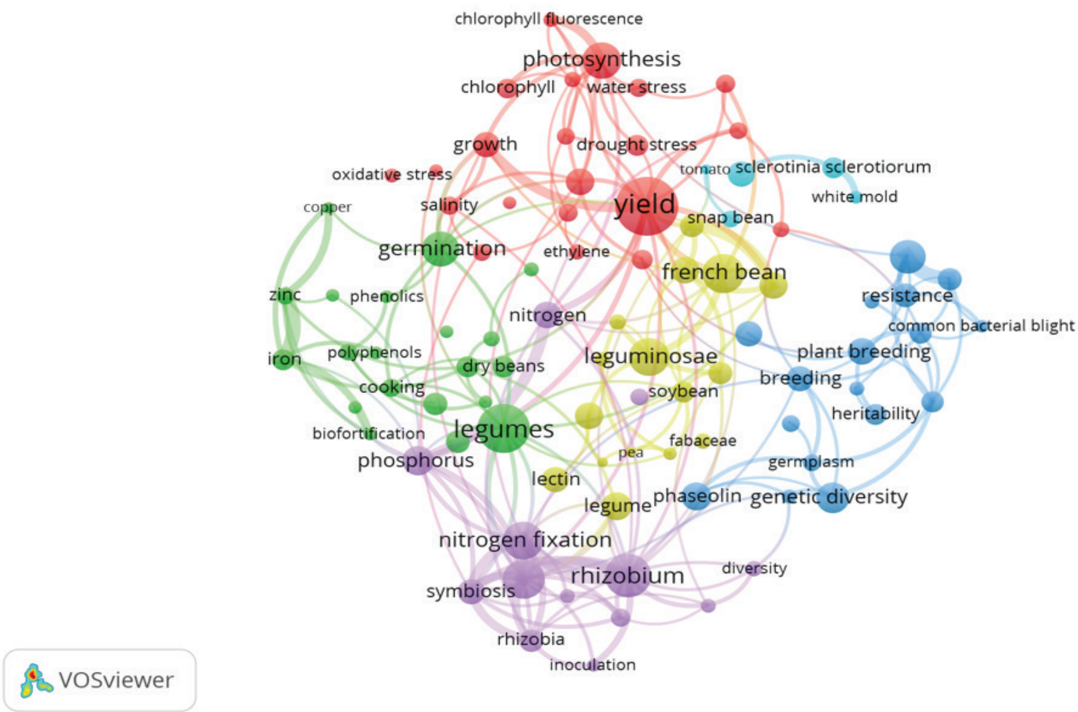

Figure 5. Scientific production regarding common bean: map of keywords indicated by the authors, 1903-2019. The construction of the network was based on publications regarding common bean in the Scopus database. Different colors represent clusters of keywords. The size of the sphere illustrates the number of times the term is indicated by authors in the publications. The connecting lines indicate the 100 strongest connections among the terms with at least 5 co-occurrences. The terms present in the Boolean search formula ("*Phaseolus vulgaris*", "common bean", and "dry bean") were excluded.

From a global perspective, the keywords related to CB research indicate the predominance of studies focused on yield, plant breeding, nutritional and technological quality, disease resistance, and adaptation to different growing environments. In addition, the five clusters show what are the main research interests around CB (Figure 5).

Over 80% of bean production in developing countries is from subsistence farming of semi-arid regions and sub-humid to humid growing environments. In these areas, most producers are small-scale farmers who use unimproved bean cultivars (Assefa et al., 2019). Common bean tends to face a high incidence of biotic and abiotic stresses, including diseases, insects, drought, and low soil fertility (Singh, 1992). These characteristics can be observed in the pattern of scientific production in the countries that showed prominence by our results. Several lines of evidence indicate that CB was domesticated at least twice – from Northern Andean and from Mesoamerican populations (Bitocchi et al., 2013; Cortés & Blair, 2018). Ecological niches for both wild populations are relatively specialized and narrow; the Mesoamerican population adapted to a bimodal rainfall regime and a mid-season dry period, typically on relatively fertile volcanic soils, in disturbed areas, or transitional forest clearings, in a near-equatorial geographical range, and the Andean wild population, growing on the Andean slopes, became more cold-adapted (Bitocchi et al., 2013).

The findings show that there can be a thematic specialization by country (Figures 3 and 5), due to different environmental and market conditions. These can also be linked with the keyword associations in the red cluster, where terms such as “growth”, “drought stress”, “irrigation”, “photosynthesis”, and “salinity” are gathered around the key term “yield”, indicating the prevalence of studies related to yield gains and adaptation to different growing environments. These results may be associated with the search for increased yields in both established productive regions, for instance, Brazil (Bezerra et al., 2021), and in regions seeking to exploit the cultivation of pulses, as can be seen in European countries (Sellami et al., 2019).

The red cluster is connected to the purple cluster by the term “nitrogen”, which refers to plant nutrition, using terms such as “rhizobium”, “phosphorus”, “symbiosis”, and “nitrogen fixation”, important themes for improving yield indicators. The growing of CB is recognized for improving soil and environmental health through symbiotic nitrogen fixation (Assefa et al., 2019; Sellami et al., 2019). The purple cluster is also related to the green cluster by the word “legumes”, involving lines of research on nutritional and technological quality (“biofortification”, “protein”, “antioxidant activity”, “storage”, “cooking time”).

The blue cluster, by its turn, concentrates terms related to “plant breeding” (“genetic diversity”, “germplasm”, “landraces”, “selection”, “molecular markers”, “disease resistance”) and to CB diseases (“anthracnose”, “angular leaf spot”, “fusarium wilt”, “common bacterial blight”). These findings can be associated with the domestication bottleneck process, which could have reduced the plant capacity response to some stresses, such as drought conditions and particular pathogens (Bitocchi et al., 2013; Schmutz et al., 2014). These evolutionary and domestication processes make CB vulnerable to a wide range of biotic and abiotic stresses, particularly as the crop has moved into new agroecological niches worldwide.

Finally, the yellow cluster highlights the results for types of CB (“French bean”, “kidney bean”, “cowpea”) and other leguminous plants (“chickpea”, “soybean”, “pea”). This cluster is characterized by a connection with all other clusters (yield, plant nutrition, nutritional and technological quality, and plant breeding), which explains its central position in the map.

CONCLUSIONS

Our methodological choice of assessing more than a century of research on common bean (CB) (from 1903 to 2019), associated with the searching in an internationally and recognized database (Scopus), allowed of an overview of the scientific production on this subject. From the historical perspective of dissemination, collaboration, and impact indicators, we mapped the main countries and lines of research and expanded the spectrum of scientific evaluation around CB research globally.

We emphasize the potential of the bibliometric approach by combining indicators of different dimensions of analysis, to subsidize studies on research impact assessment (RIA). Therefore, our study establishes a basis for policy refinement to support research and strategic planning in science, technology and innovation.

Our results show that the first publication in the Scopus document database goes back to 1903. Its historic trajectory to 2019 is marked by the predominance of studies on yield, plant breeding, nutritional and technological quality, disease resistance, and adaptation to different growing environments. These research topics are associated with the evolutionary and domestication processes of this legume. Over time, CB became vulnerable to a wide range of biotic and abiotic stresses, mainly because the culture shifted to new agroecological niches throughout the world. These findings point to a thematic specialization by producing regions (countries) that may also be aligned with specific market conditions.

The strong protagonism of the United States in the scientific production and dissemination on this topic is evidenced by the net research output, the citation impact of its publications, and the connections formed within collaboration networks, in which it is the central player, intensely interacting with countries such as Brazil, France, Spain, Germany, Mexico, and Colombia. The US prominence, and that of other countries can be related to the existence of world reference centers for the management and conservation of genetic resources. These institutional arrangements, associated with scientific and technological projects of global scope, genetic databases, and other initiatives can promote the collaboration between countries and intensify the dissemination and impact of scientific production, therefore putting these nations in the CB scientific spotlight.

Future research can enrich the discussion conducted in this paper, by analyzing other bibliometric indicators internationalization, performance at the researcher and organization levels, and impact factor, among others) and alternative metrics that allow of the assessment of the effect and repercussion of scientific production on the social web (altmetrics).

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