

A bibliometric analysis of global publications on flax (*Linum usitatissimum* L.) disease during 2001-2021


Keten (*Linum usitatissimum* L.) hastalığı üzerine 2001-2021 döneminde yapılmış küresel yayınların bibliyometrik analizi

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ARTICLE INFO	ABSTRACT
<p>Article history: Recieved / Geliş: 15.01.2023 Accepted / Kabul: 07.04.2023</p> <p>Keywords: Bibliometric analysis Flax <i>Linum usitatissimum</i> Diseases of flax VOSviewer</p> <p>Anahtar Kelimeler: Bibliyometrik analiz Keten <i>Linum usitatissimum</i> Keten hastalıkları Vosviewer</p> <p>✉ Corresponding author/Sorumlu yazar: Sitora KARİMOVA karimova.uzb@umail.uz</p> <p>Makale Uluslararası Creative Commons Attribution-Non Commercial 4.0 Lisansı kapsamında yayınlanmaktadır. Bu, orijinal makaleye uygun şekilde atıf yapılması şartıyla, eserin herhangi bir ortam veya formatta kopyalanmasını ve dağıtılmasını sağlar. Ancak, eserler ticari amaçlar için kullanılamaz. © Copyright 2022 by Mustafa Kemal University. Available on-line at https://dergipark.org.tr/pub/mkutbd</p> <p>This work is licensed under a Creative Commons Attribution-Non Commercial 4.0 International License.</p> 	<p>Researchers around the world have published articles on flax (<i>Linum usitatissimum</i> L.) and its diseases. However, there is no bibliometric analysis of flax and its diseases in the Scopus database. The purpose of this work is to analyze the scientific results in the field of flax and its diseases and follow its evolution worldwide based on the data collected from the Scopus database. In the article, global scientific publications related to flax and its diseases were analyzed by a bibliometrician. In this study, a total of 243 articles published during 2001-2021 years were evaluated. The results show that the number of articles in the database has increased year by year, with Canada, Australia and the United States occupying the core positions, accounting for 64.6% of the total published articles worldwide. P.N. Dodds is the author with the most published articles. This paper summarizes several possible research ideas and the systematic bibliometric analysis will help research groups and researchers to understand global research trends in flax and its diseases and to focus future research. Also, results obtained in this systematic review of flax-related articles by using statistical and visual bibliometric analysis can provide important and detailed information to scientists involved in research on it.</p> <p>ÖZET</p> <p>Dünyanın dört bir yanındaki araştırmacılar keten (<i>Linum usitatissimum</i> L.) hastalıkları hakkında makaleler yayınladı. Ancak Scopus veritabanında keten ve hastalıklarının bibliyometrik analizi yoktur. Bu çalışmanın amacı keten ve hastalıkları alanındaki bilimsel sonuçları analiz etmek ve Scopus veri tabanından toplanan verilere dayanarak dünya çapındaki gelişimini takip etmektir. Makalede keten ve hastalıkları ile ilgili küresel bilimsel yayınlar bibliyometrik olarak incelenmiştir. Bu çalışmada 2001-2021 yılları arasında yayınlanmış toplam 243 makale değerlendirilmiştir. Sonuçlar veritabanındaki makale sayısının yıldan yıla arttığını Kanada, Avustralya ve Amerika Birleşik Devletlerinin dünya çapında yayınlanan toplam makalelerin 64.6 % sını oluşturan çekirdek konumları işgal ettiğini gösteriyor. P.N.Dodds bu konuda en fazla makalesi olan yazardır. Bu makale birkaçolası araştırma fikrini özetlemektedir ve sistematik bibliyometrik analiz araştırma gruplarının ve araştırmacıların keten ve hastalıklarındaki küresel araştırma eğilimlerini anlamalarına ve gelecekteki araştırmalara odaklanmalarına yardımcı olacaktır. Ayrıca istatistiksel ve görsel bibliyometrik analiz kullanılarak ketenle ilgili makalelerin bu sistematik derlemesinde elde edilen sonuçlar bu konuda araştırma yapan bilim insanlarına önemli ve ayrıntılı bilgiler sağlayabilir.</p>
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INTRODUCTION

A common oil seed crop all over the world, *Linum usitatissimum* L., also known as flax or flaxseed, belongs to the family *Linaceae* (Raole & Raole, 2022). The seeds of many of the important industrial crops are grown around the world for their seed oil and fiber, one of them being the linseed plant. (Patade et al., 2008; Vlčková et al., 2022). According to FAOSTAT, the world harvested area of flaxseed has increased by over 31% from 3.14 million hectares in 2018 to 4.14 million hectares in 2021 (FAOSTAT). It has been demonstrated that flaxseeds contain essential constituents that can be made bioavailable for different applications within the food industry, including nutraceuticals, cosmetics, and nutritional supplements through the application of different bioprocessing techniques (Dzuvor et al., 2018). The uses of flax products are extremely varied and include not only the production of fabrics (some of which aid in the advancement of astronautics), the nuclear industry, the military, and manufacturing ones such as producing the uniform for miners and oil workers), but also the production of flaxseed oil, which is used in pharmacology, and the wax used in spaceships (Kajla et al., 2015; Sapojnikova et al., 2020). In addition to the Indian subcontinent and southeast African highlands, flax has been adapted to survive in a wide range of eco-geographic regions throughout the world, from the cool highlands of Eurasia to the high latitudes and cool conditions of the Indian subcontinent (Sertse et al., 2021). The most prevalent and high-alpha-linolenic-acid flaxseed is brown, whereas there are two varieties of yellow flaxseed: Omega and Linola (Conforti & Cachaper, 2009). Consumer awareness about the relationship between diet and health has increased demand for flaxseed. Flaxseed is regarded as a potential functional food ingredient because it provides numerous health benefits in addition to nutritional value (Eyres, 2015; Öksüz, 2015). However, it is an underutilized crop that has gained prominence in recent decades due to its unique nutrient profile, particularly omega-3 fatty acids, lignans, and fiber (Goyal et al., 2014). The range of flaxseed's total protein content is between 20 and 30%, with 80% of it being globulins and 20% glutelin (Hall et al., 2006). A 100 g serving of flaxseed has 60–300 mg of lignans (Flower et al., 2014). There is an increasing demand for flaxseed as a functional food in the global food system. It is possible to define functional food as foods or ingredients that may provide physiological benefits or aid in the prevention and treatment of illness (Al-Okbi, 2005). Although there are numerous potential therapeutic advantages for using flaxseed to treat disorders affecting women, no research has been done in this area to date (Sourinejad et al., 2019).

Plant ailments and pests pose risks to the security of the world's food supply (El-Saadony et al., 2022). They have ability to dramatically lower the quantity and quality of agricultural products (Bakr et al., 2022). Despite the development of potentially high-yielding flax variants, environmental factors significantly reduce flax productivity (Dmitriev et al., 2017). In addition to a few viruses and a phytoplasma, fungi are the primary cause of flax diseases. Bacteria or nematodes do not cause any major diseases in flax. All varieties of flax, including linseed, oil flax, and fiber flax (*Linum usitatissimum* L.), are susceptible to fungal infections. There may be variations in how each kind of flax reacts to particular infections or races of the same disease. In the world's flax-growing regions, there are regional differences in the frequency, severity, and significance of flax diseases (Muir & Westcott, 2003). Rust is the issue that has the greatest potential to harm flax. The last severe rust epidemic occurred in the 1970s (Parthasarathy et al., 2021). Fusarium wilt, a fungal disease, is the most economically harmful of the diseases that modern flax cultivars are subject to (Kanapin et al., 2021). As a result of the disease outbreak, 80–100% of flax harvest could be lost. Moreover, the fungus' chlamydospores can survive for up to 50 years in the infected soil and are extremely difficult to eliminate (Houston, 1949). Verticillium wilt poses a serious danger to a variety of agricultural crops (Blum et al., 2018). Each stage of disease development is critical in the pathogen life cycle and necessitates specific conditions (Stafecka et al., 2017). Verticillium dahliae causes yield losses as well as degraded fibers that are challenging to textile industry. One of the most significant flax diseases, powdery mildew is particularly detrimental to the yield and oil or fiber quality of the plant (Speck et al., 2022). Powdery mildew, caused by *Oidium lini*, is an important diseases of flax (*Linum usitatissimum*) in western Canada (Rashid & Duguid, 2005).

Bibliometric analysis is a technique for completely, methodically, and impartially summarizing historical accomplishments and development trends (He et al., 2019) With the aid of mathematics and statistics, computer analysis and information visualization technology, as well as the examination of the literature, it can also investigate potential future research areas for the discipline (Bezak et al., 2021). A bibliometric study uses quantitative methods to objectively map the research field and analyze the bibliographic data (Tigre et al., 2023), (Zupic & Čater, 2015). In addition to other pieces of evidence, it highlights the most significant works and authors, the development of the most often used keywords, the most pertinent subjects, and the predominating consequences. The network analysis visualization method completes the examination of the research area (Cobo et al., 2011; Tigre et al., 2023). By displaying the evolution, research hotspots, and frontier knowledge of a given research field, it may graphically depict the dynamic development of that field. The goal of this study is to thoroughly and methodically evaluate and present bibliometric data analysis using VOSviewer. First-time users can easily follow the instructions for using VOSviewer thanks to the step-by-step analysis that was supplied (Al Husaeni & Nandiyanto, 2021). But very few studies have employed bibliometric analysis to extract information (Huang et al., 2022).

The purpose of this article was to comprehensively analyze the scientific activities of researchers during this period through bibliographic analysis of articles published in the Scopus database on flax and its diseases during 2001-2021. In addition, it provides a global analysis of scientific cooperation and countries' research productivity in this field, providing information on comprehensive views.

MATERIALS and METHODS

This article is based on bibliometric analysis of scientific publications in the Scopus database. Article information is obtained from the Scopus database. The retrieved data are articles published between 2001 and 2021 years. Before the 1990s, flaxseed oil and its sub-products were primarily used for the production of cloth (linen) and papers, while flaxseed oil and its sub-products were also used in the formulation of animal feed (Singh et al., 2011). The potential health benefits associated with some of flaxseed's biologically active components have led to increased interest in diet and disease research over the past two decades. As well as providing a range of nutrition characteristics, linolenic acid (ALA), short chain polyunsaturated fatty acids (PUFAs), soluble and insoluble fibers, phytoestrogenic lignans (secoisolaricresinol diglycoside-SDG), proteins, and flaxseeds also contain a number of antioxidants (Oomah, 2001; Touré & Xueming, 2010; Singh et al., 2011). Information was extracted from the published scientific works using the following 3 keywords: *flax*, *Linum usitatissimum* and *diseases of flax*. For this, a total of 243 publications were downloaded and maps of the collected data were drawn using MC Excel and VOSviewer programs. Mapchart.com was used to draw the map. The functionality of VOSviewer is especially useful for displaying large bibliometric maps in an easy-to-interpret way (van Eck & Waltman, 2010). The citation database is with a wide variety of fields Agricultural and biological Sciences, Biochemistry, Genetics and Molecular Biology, Immunology and Microbiology, Environmental Science. Our research framework is shown in Figure 1.

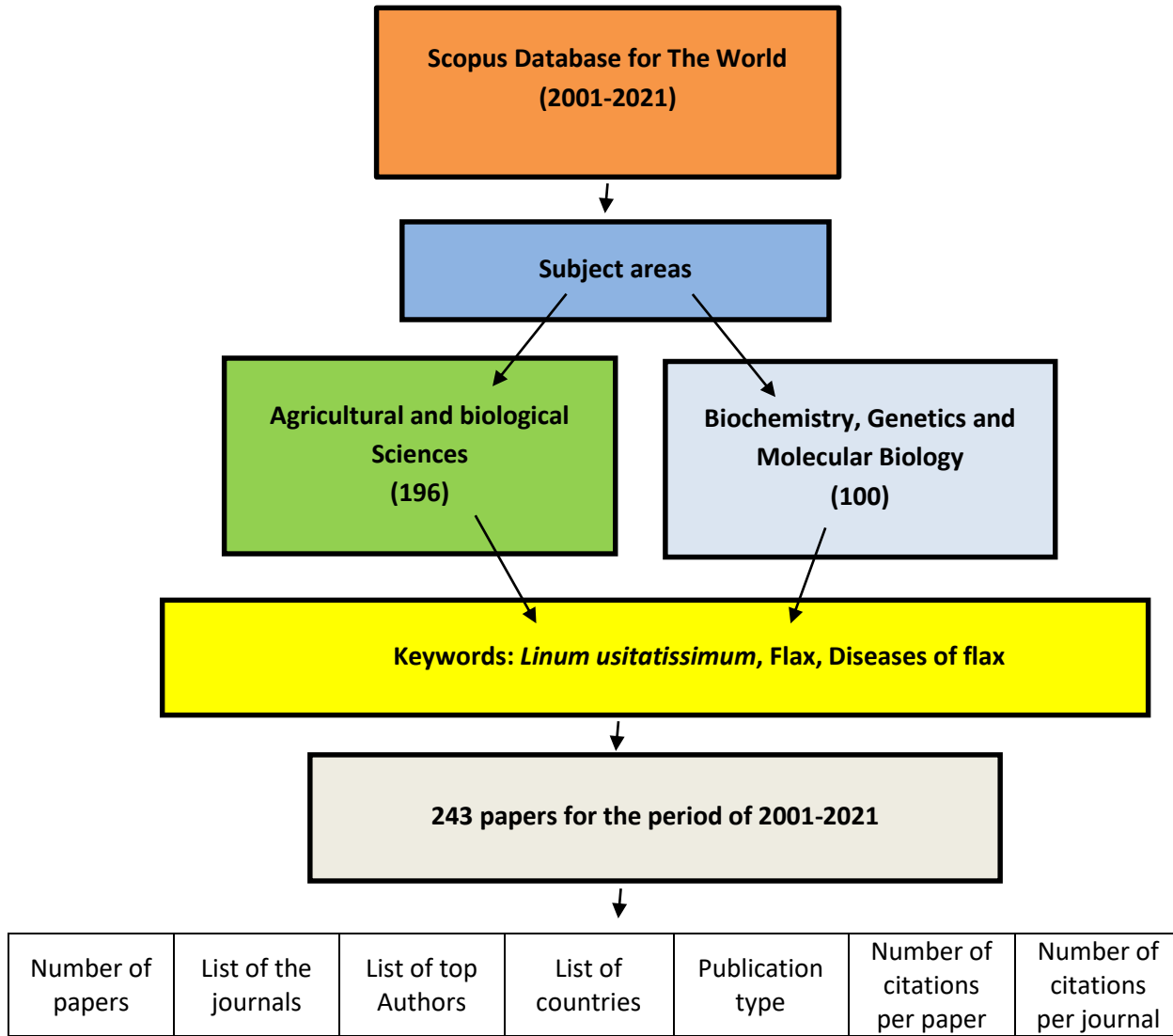


Figure 1. Research framework followed in this study

Şekil 1. Bu çalışmada izlenen araştırma çerçevesi

RESULTS and DISCUSSIONS

During the period of 2001-2021, the number of publications devoted to the diseases of flax plants worldwide is large. The Figure 2 shows the annual increase and decrease in published research articles. In 2001, there were six articles on flax plant disease research. In 2002, this figure decreased to two. In 2004, the number of publications on flax plant diseases increased dramatically. The publication of 16 articles in these years means that research has almost doubled compared to previous years. In 2005, this indicator decreased, and by 2006, it increased significantly. The annual increase rate of publishing research papers is certainly not uniform and it is constantly changing. After that, the highest growth rate was observed in 2009. This year reached the highest with 20 publications and the lowest was in 2002 with 4 publications. In 2008 and 2011, the number of publications is 19. However, 18 publications in 2007 dropped to 13 by 2010. In the diagram, the number of publications on flax disease in the period of 2012-2015 was 10-12. But between 2016-2018, this indicator decreased again, which corresponds to 2018 with 4 publications. In 2019-2021, the number of publications increased sharply again and reached 11 in 2021. There were 7 occasions of less than 10 publications in two decades according to the graph shown below (Figure 2). Partial stability can be seen in the remaining years.

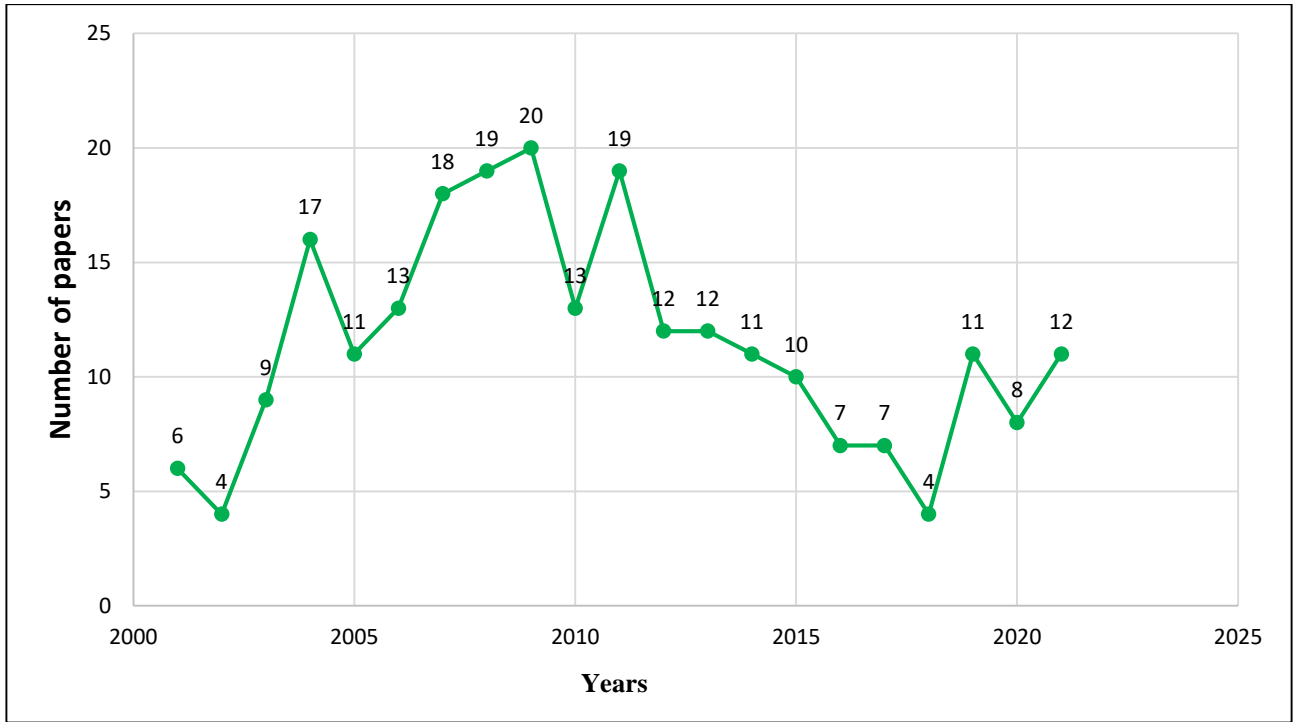


Figure 2. Number of papers of flax plant diseases by the year of publication

Şekil 2. Yayın yılına göre keten bitkisi hastalıkları konusundaki makale sayısı

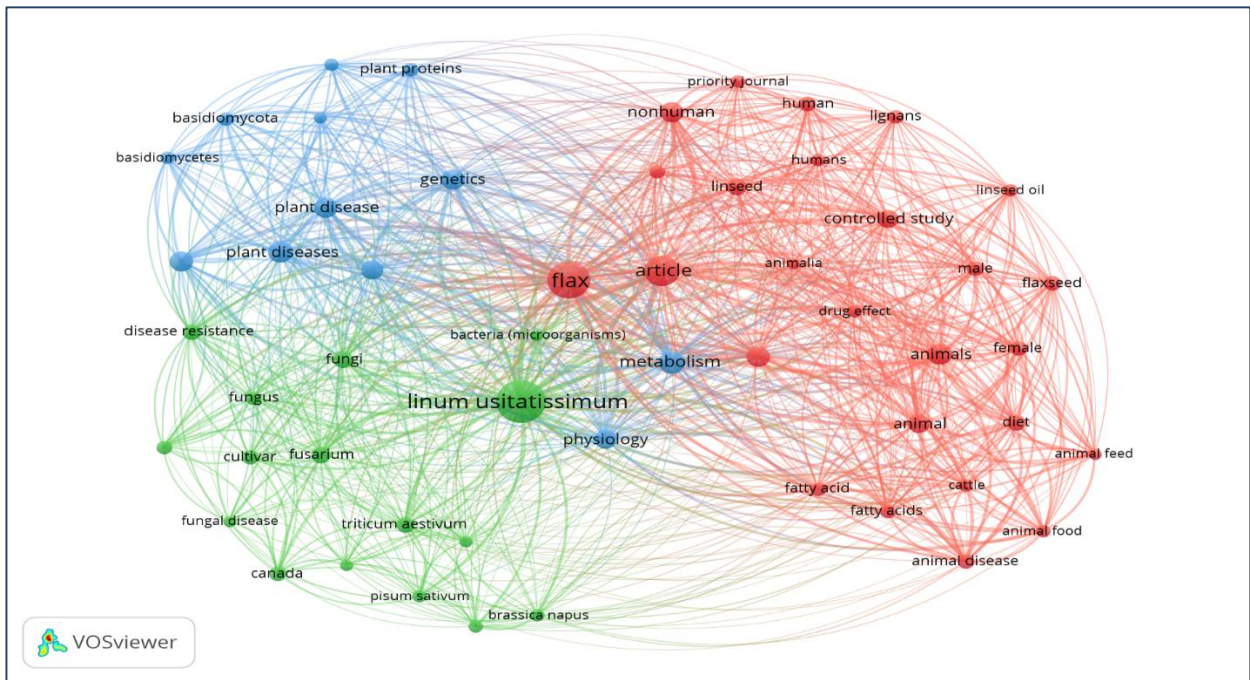


Figure 3. Keyword co-occurrence analysis using VOSviewer

Şekil 3. VOSviewer kullanarak anahtar kelimelerle birlikte oluşum analizi

A total of 3126 keywords were used in 243 articles. In 54 of them, keywords that were repeated at least 15 times were extracted. Of these, the most used keyword is *Linum usitatissimum*, which appears 202 times (Total link strength 1366), flax 154 times (Total link strength 1239), plant diseases 53 times (Total link strength 519) were used. Big clusters and their connection to other keywords could be seen in Figure 3.

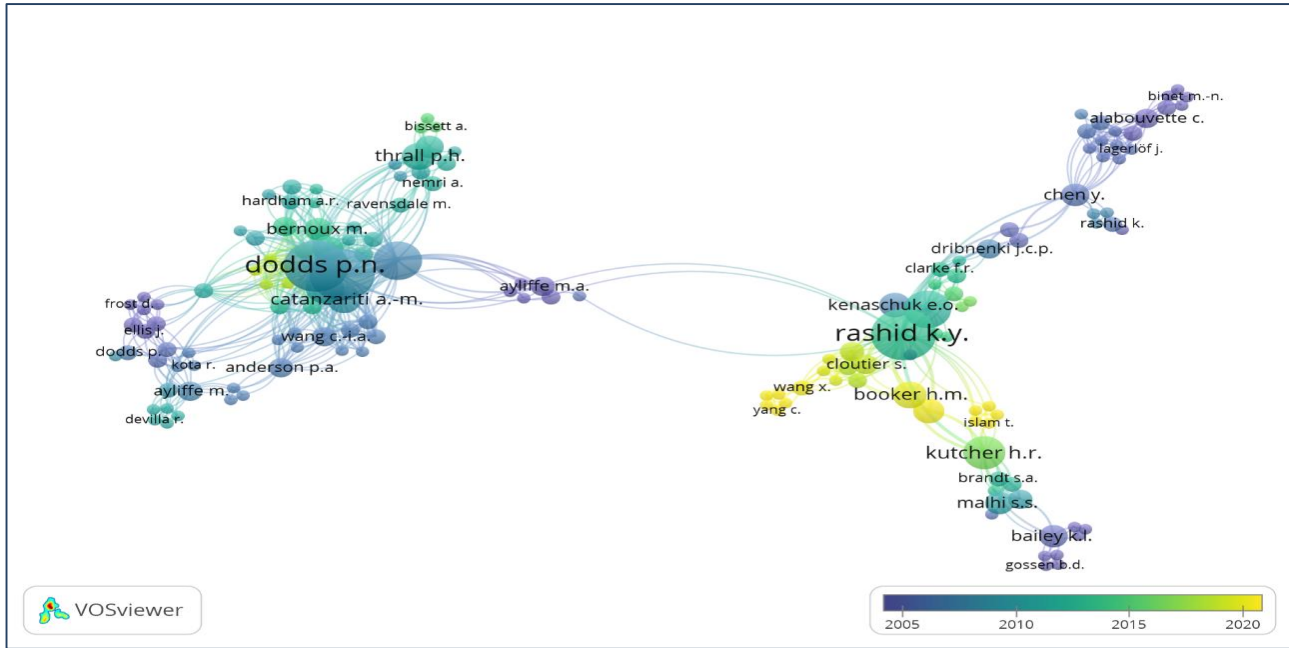


Figure 4. Top authors published of flax plant diseases issue
 Şekil 4. Keten bitki hastalıkları konusunda yayınlanan en iyi yazarlar

When the authors' publications were analyzed in the VOSviewer program, it was found that a total of 850 authors published 243 co-authored articles (Figure 4). As the number of articles increased, the correlation decreased. A total of 21 articles were published by three authors, Dodds, Ellis, and Rashid. Dodds and Ellis have 51 links with other authors, and Total link strength is 118. Rashid has 33 links with other authors and the total link strength is 72. Since not all 850 authors are connected to each other, the VOSviewer program divided the 154 most connected authors into 12 clusters. Dodds and Ellis formed the largest cluster, and they published mostly in 2008, and Rashid, K.Y. published more articles in 2012. In recent years, Booker, H.M. and Wang X. is doing more work on flax. We can see that in two large clusters Rashid, K.Y. and Ellis J.G. are connected to each other through Ayliffe, M.A.

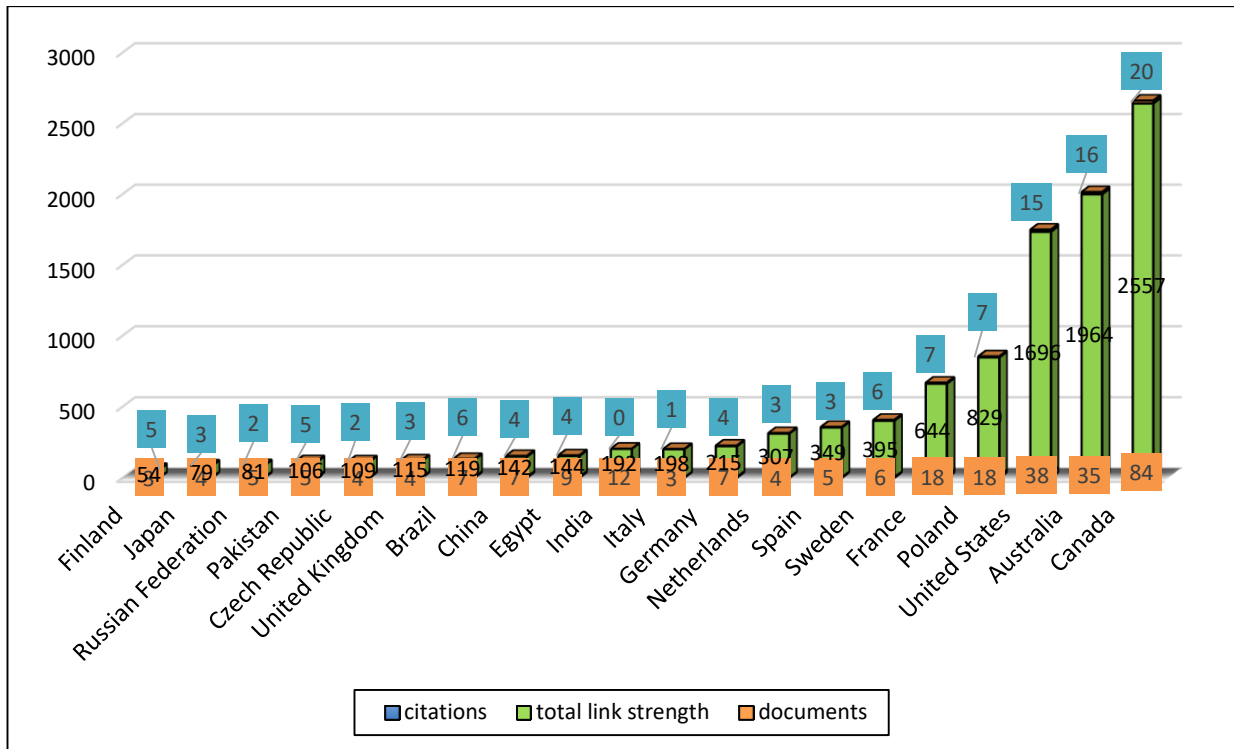


Figure 5. Top published and cited countries
 Şekil 5. En çok yayınlanan ve alıntı yapılan ülkeler

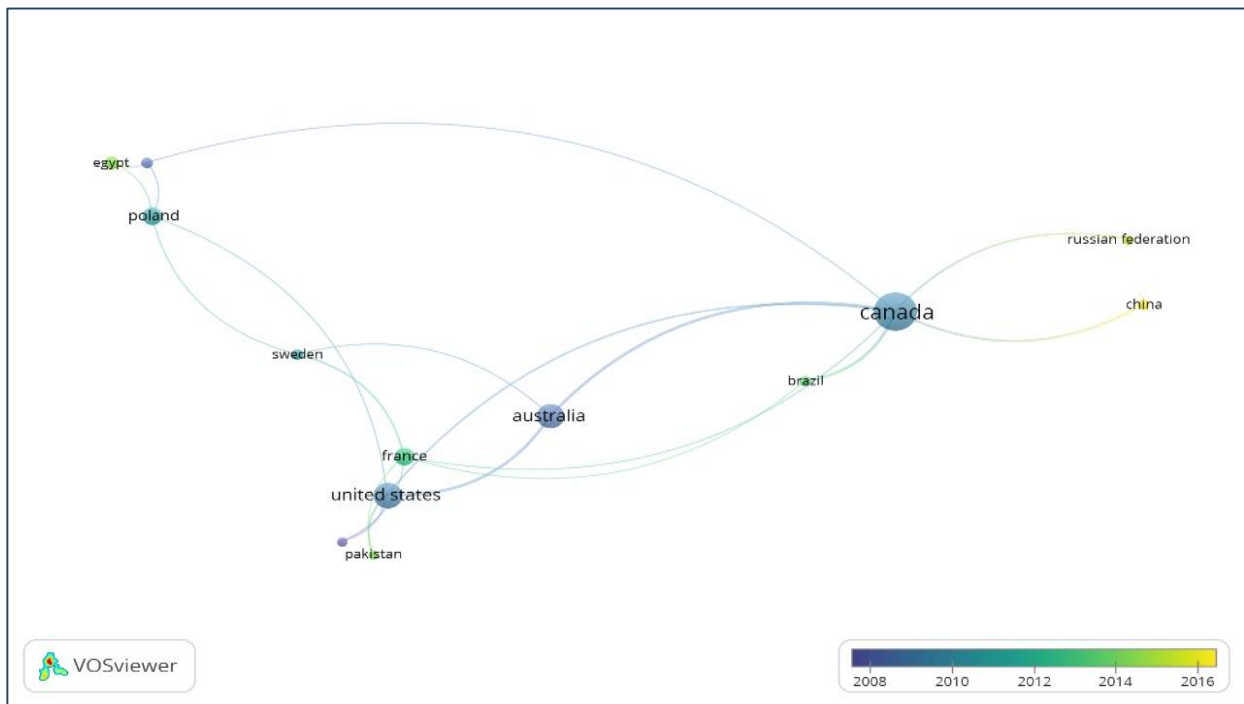


Figure 6. Top published and cited countries
 Şekil 6. En çok yayınlanan ve alıntı yapılan ülkeler

During the years 2001-2021, scientists conducted scientific research on flax in a total of 47 countries (Figure 5). When publishing at least 5 articles in the VosViewer program, it was found that 14 out of 47 countries have a threshold. Of these countries, the country with the most publications is Canada. A total of 84 articles have been published over 21

years and these articles have 2557 citations. It was found that there are 38 publications and 1696 citations in the United States, and 35 publications and 1964 citations in Australia. Citations may increase year after year. It can be seen here that there are 18 publications by French and Polish scientists, and 12 by Indian scientists. In Figure 6, in 2008-2009, the United States and Australia jointly conducted scientific research on flax, and in 2010, Canada conducted the most work. In recent years, we can see that scientific works are more connected with China.

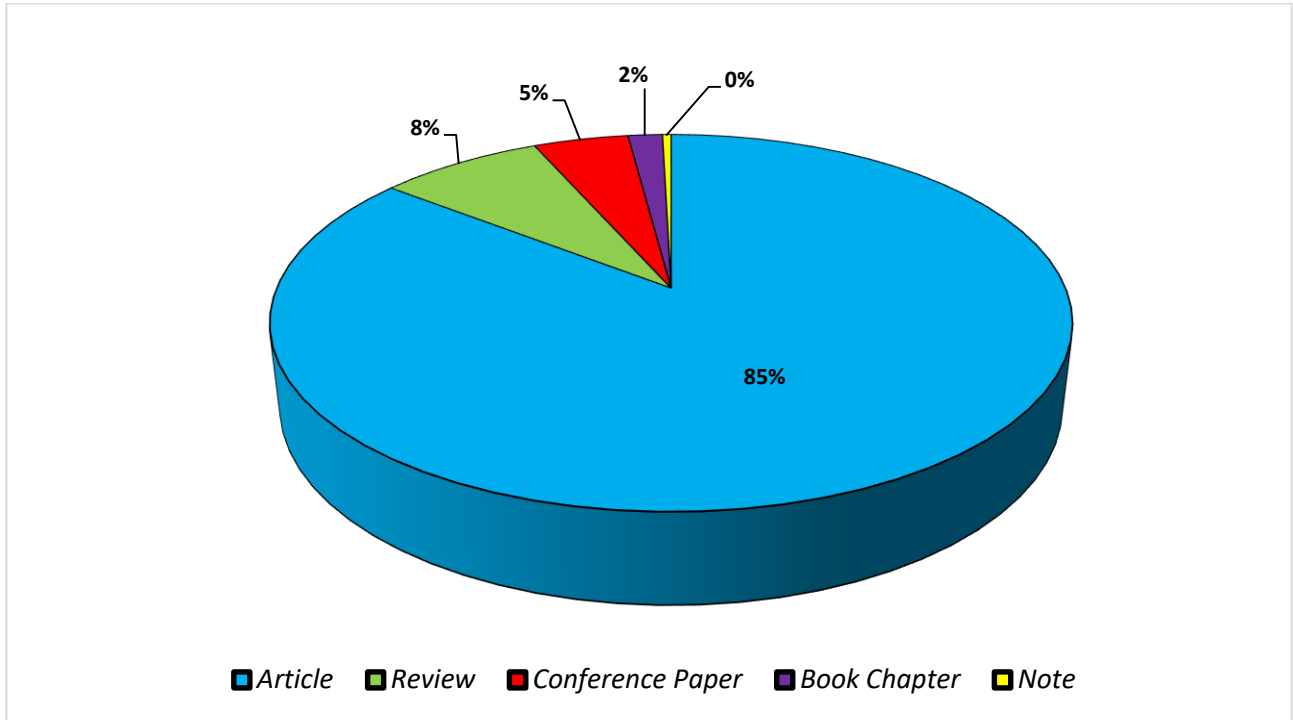


Figure 7. Publication type on flax plant diseases in the world

Şekil 7. Dünya keten bitkisi hastalıkları ile ilgili yayın türü

Figure 7 shows five different types of publications including articles, reviews, conference papers, book chapters, and books, described in more detail in Figure 6. There is no doubt that the greatest number of publications on this topic are in the form of articles, making up 85 percent, followed by 8 % publications in the form of reviews. A total of eleven papers have been published as a result of the conference. Moreover, there have been four book chapters and a book published as a result of the conference.

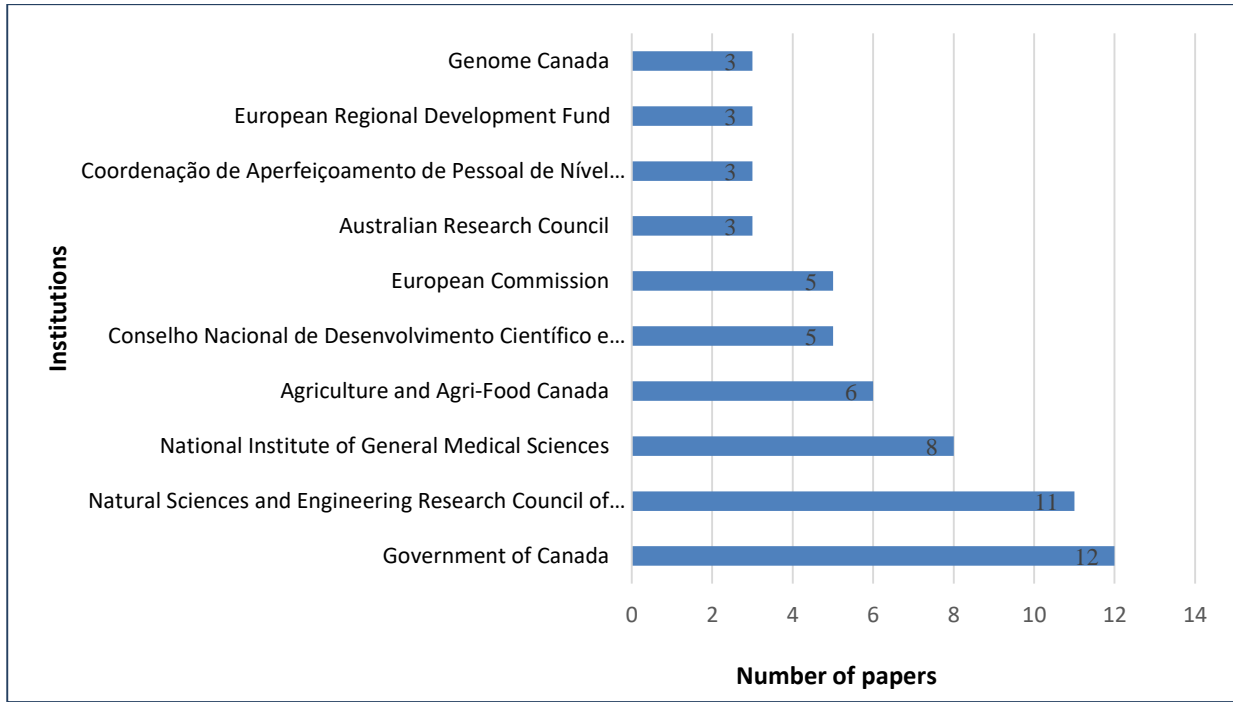


Figure 8. Top ten Funding agency on flax plant diseases issue

Şekil 8. Keten bitkisi hastalıkları konusunda ilk on Finans kuruluşu

During the years 2001-2021, a total of 93 institutes financed the flax industry. Of these, the top 10 institutions are described in Figure 8. Among them, the Government of Canada financed twelve scientific works. The National Institute of General Medicine of Sciences and the Natural Sciences and Engineering Research Council of Canada participated in financing eleven times. Also, four of the top 10 institutions belong to Canada. Flax industry is important for Canada, where flax is mainly grown for its oil. Over the centuries, flax production spread to Europe, Africa and North America. Canada is the world's largest producer and exporter of flax, with annual exports of 150-180 million Canadian dollars.

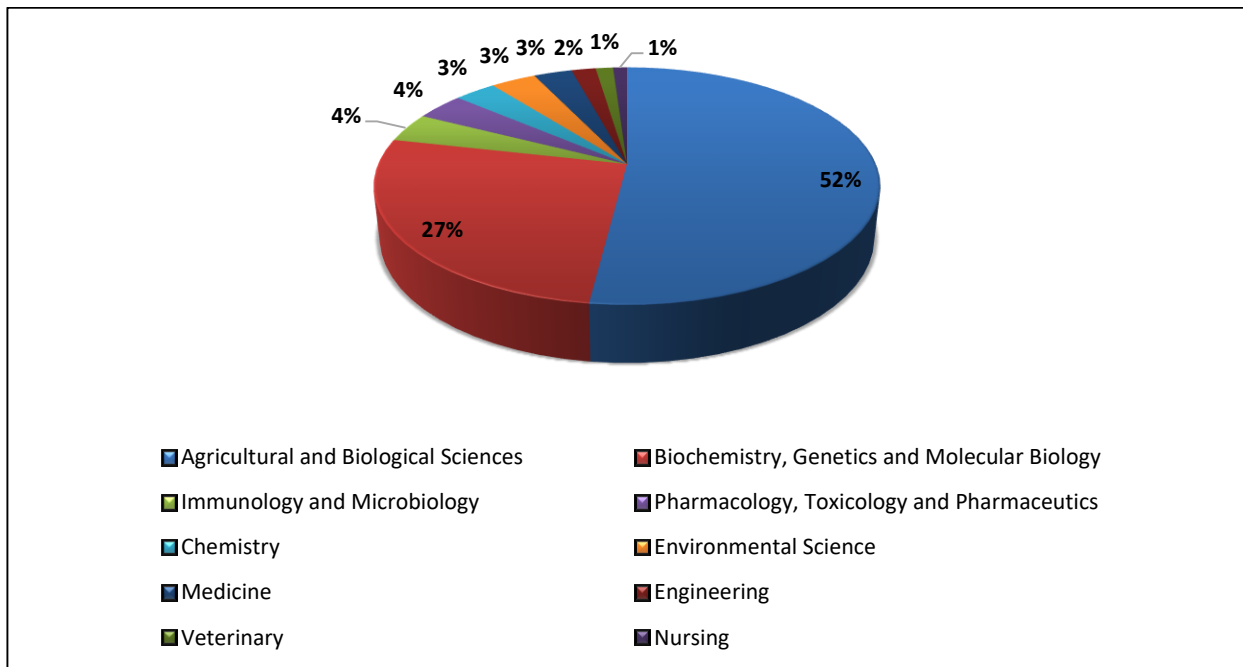


Figure 9. Analysis by subject area flax and its diseases

Şekil 9. Konu alanına göre analiz keten ve hastalıkları

Subject area classification for flax and its diseases is presented in Figure 9. 52% of scientific research was in the fields of Agricultural and Biological Science, Biochemistry and Genetics, and 27% in Molecular Biology. Scientific researches were carried out partly in the areas of Immunology and Microbiology and Pharmacology, Toxicology and Pharmaceutics. In other areas, flax was not very important. But in recent years, the discovery of the beneficial aspects of flax has led to an increase in interest in this plant in other areas as well. Flaxseeds have nutritional characteristics and are rich source of ω -3 fatty acid: α -linolenic acid, short chain polyunsaturated fatty acids, soluble and insoluble fibers, phytoestrogenic lignans, proteins and an array of antioxidants (Oomah, 2001b; Touré & Xueming, 2010; Ivanov et al., 2011; Singh et al., 2014).

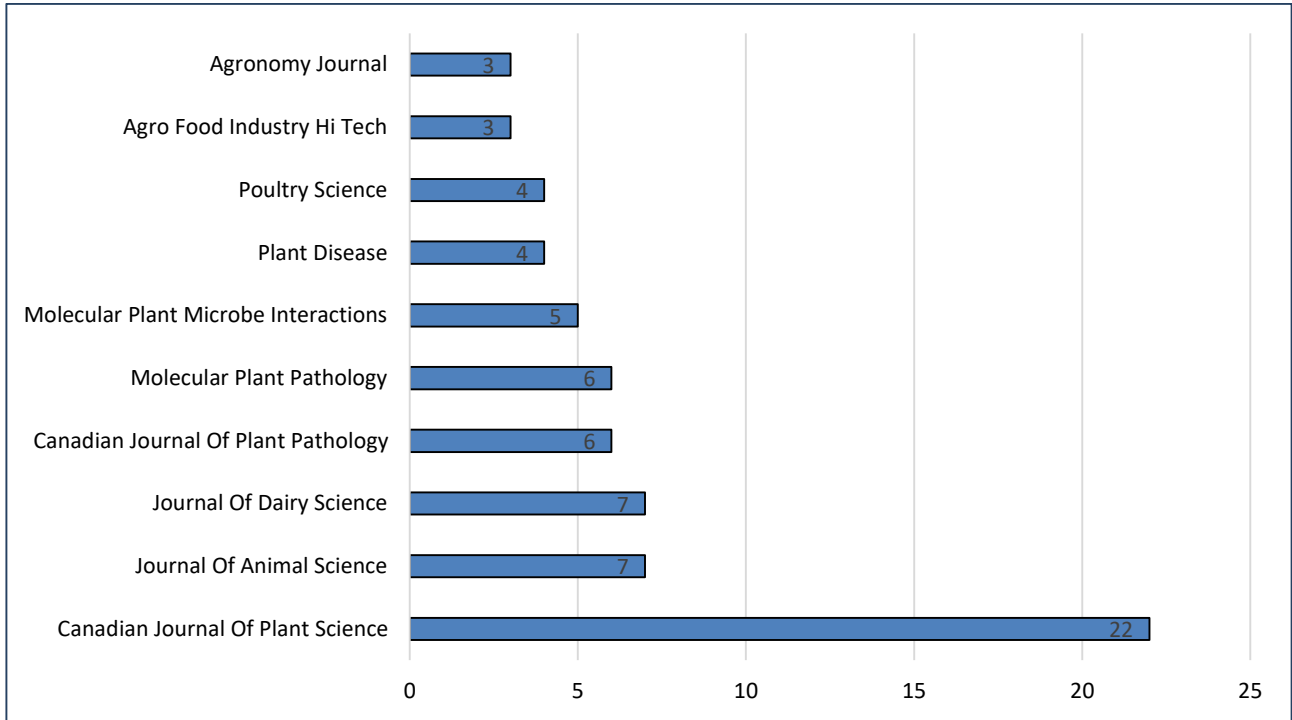


Figure 10. Top cited journals on flax in Scopus database

Şekil 10. Scopus veri tabanında keten üzerine en çok alıntı yapılan dergiler

The top 10 journals are shown in Figure 10. According to the results of the analysis, 243 articles were published in 138 journals. Canadian Journal of Plant Science, which published the most articles, had 22 articles cited 340 times. It has published 7 articles with 172 and 336 citations in Journal of Animal Science and Journal of Dairy Science. Another journal with high citations is the Journal of Molecular Plant Pathology, with 409 citations.

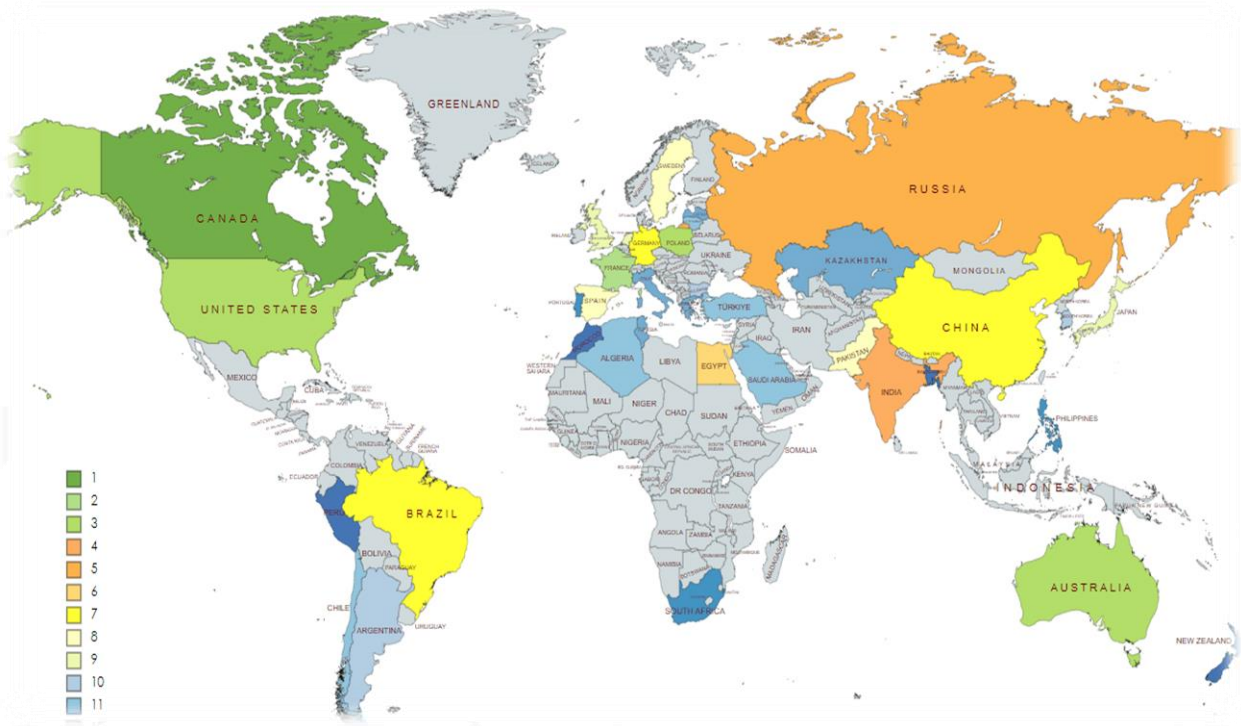


Figure 11. Geographic locations of the study on *L. usitatissimum* classification
 Şekil 11. *L. usitatissimum* sınıflandırması üzerine olan çalışmaların coğrafi konumları

The maximum number of publications are from Canada, Australia, United State, France and Poland in Scopus (Figure 11). The geographical locations, where the research on *L. usitatissimum* classification is carried out, is shown in Figure 11 using the Mapchart.net. A total of 47 countries have published articles on flax. According to the analysis, more flax is grown in the countries of the continents of North and South America, Asia, Europe, and Australia, and scientific research work has been conducted on this. In the countries of the African continent, we can observe that there is relatively little scientific research. (Mainly in Egypt, Algeria, Morocco, South Africa). It became known that articles were not published in the Scopus database in the countries of Central Asia.

Almost every component of the linseed plant is used in some way. Oil found in seeds, which is used for food purposes after refinement (Singh et al., 2012). Until the 18th century, Europe's linen industry was thriving. But with the development of power spinning, cotton displaced flax as the most significant and popular fiber. Today, because of its low output and high price, flax is a prestigious material. Clothes made of linen are typically intended for warm weather, high fashion, or formal use (Dai, 2006). Flax fields has been developing in recent years due to its unique nutritional composition, omega-3 fatty acids and lignans (flax fiber), and it is one of the crops that are widely cultivated year after year. Flax grows naturally, needs very little water, and little in the way of fertilizers or pesticides. All plant parts are used during harvest, leaving no waste behind.

Bibliometric analysis is the most effective way to help in studying the characteristics of this field. It also allows to identify publications, top authors and institutions about the scientific volume, growth and spread of this field.

The Bibliometric analysis is the most effective way to help in studying the characteristics of this field. It also allows to identify publications, top authors and institutions about the scientific volume, growth and spread of this field.

Analysis of flax and its diseases was based on publication data obtained from the Scopus database. VOSviewer software helped to analyze keywords, influential authors and their groups. According to our analysis, Agricultural and Biological Sciences, Biochemistry, Genetics and Molecular Biology were found to be the fields with the highest number of publications. The Canadian Journal of Plant Science led the way in publishing articles. Researchers have mainly published articles and conference materials, most of them are from Canada, USA and Australia. Over the past

20 years, Canada has provided the most funding for projects flax and its diseases. Moreover, Canadian reserchers are the most productive and influential because they account for the most publications with a high number of citations and high h-index. But another level all articles were written by a small number of prolific authors, with relatively poor collaborative ties emerging across time between authors, institutions, and countries. Science mappings based on indicators such as the most commonly used keywords, citation and co-citation, and collaboration are also developed for further analysis. The research on flax and its deseases is booming, and international exchanges and cooperation need to be further strengthened. Studying its diseases will help to get a high and healthy harvest. This supports economic efficiency at a time when global demand for food is increasing.

STATEMENT OF CONFLICT OF INTEREST

The author(s) declare no conflict of interest for this study.

AUTHOR'S CONTRIBUTIONS

The contribution of the authors is equal.

STATEMENT OF ETHICS CONSENT

Ethical approval is not applicable, because this article does not contain any studies with human or animal subjects.

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