KONYA FOOD AND AGRICULTURE UNIVERSITY
GRADUATE SCHOOL OF NATURAL & APPLIED SCIENCES
DEPARTMENT OF INDUSTRIAL ENGINEERING

TECHNOLOGY SELECTION WITH MULTI-CRITERIA DECISION MAKING METHODS AND DATA ANALYSIS ALGORITHMS USING PATENT DATA

MASTER OF SCIENCE THESIS

M**t U**r G***N**

Konya
NOVEMBER, 2022

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Department of Industrial Engineering

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This study titled **"Technology Selection with Multi-Criteria Decision Making Methods and Data Analysis Algorithms Using Patent Data"** prepared by M****t U**r G***N has been accepted with consensus by the following jury on 01/11/2022 as a **MASTER THESIS** in the DEPARTMENT OF INDUSTRIAL ENGINEERING.

Supervisor	: Prof. Dr. D****ş T****r Ş*N Konya Food and Agriculture University	…….
Jury Head	: Prof. Dr. S*******n E***n K***N Konya Technical University	…….
Jury Member	: Doç. Dr. A*i K***Ç Konya Food and Agriculture University	…….

I certify that this thesis which has been accepted by the jury satisfies all the requirements as a thesis for the degree of Master of Science.

Prof. Dr. D****ş T****r Ş*N
Head of Department

Approval of the Graduate School of Natural and Applied Sciences

Prof. Dr. B***ç C****N
Director (acting)

ABSTRACT

TECHNOLOGY SELECTION WITH MULTI-CRITERIA DECISION MAKING METHODS AND DATA ANALYSIS ALGORITHMS USING PATENT DATA

G***N, M****t U**r

Master of Science Thesis, Department of Industrial Engineering

Supervisor: Prof. Dr. D****ş T****r Ş*N

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The ever-increasing pace of technology development and the consequent shortening of the life cycles of Technological Studies increases the importance of the question of which area, when and how much should be invested by researchers and technology developing companies. In addition, the fact that technological studies and innovation are nowadays shifting from an intra-sectoral to an interdisciplinary and inter-company/group structure increases the need for information for companies to identify the areas and companies they should collaborate with. In this context, for an organization working in a certain field and aiming to innovate, the question of which technologies it should invest in to take its work forward is among the most important problems of innovation today. In addition, although patents contain a lot of data, it is very difficult to effectively examine tens of thousands or even more patents in a field for the desired purposes. In particular, text-based patent studies cannot provide an effective solution due to the terms that are written in the same way and have different meanings or are used for independent functions in very different fields. With this study, it is aimed to retrieve the patents defined within a specified technology by using the CPC Patent Classification and then enriching and analyzing the data retrieved by using data mining algorithms and applying the Entropy-weighted TOPSIS method to propose an objective and innovative method for solving the Technology Selection Problem by using patent data and data analysis algorithms and multi-criteria decision making methods.

Keywords: Technology Selection, Patent Analysis, Multi-Criteria Decision Making, FP-Growth, Entropy weight TOPSIS

ÖZET

PATENT VERİLERİNDEN YARARLANILARAK ÇOK KRİTERLİ KARAR VERME YÖNTEMLERİ VE DATA ANALİZİ ALGORİTMALARI İLE TEKNOLOJİ SEÇİMİ

G***N, M****t U**r

Yüksek Lisans Tezi, Endüstri Mühendisliği Anabilim Dalı

Danışman: Prof. Dr. D****ş T****r Ş*N

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Teknoloji geliştirmenin her geçen gün hızının artması ve dolaylı olarak Teknolojik Çalışmaların hayat döngülerinin oldukça kısalması, araştırıcıların ve teknoloji geliştiren şirketlerin hangi alana, ne zaman ve ne miktarda yatırım yapmaları gerektiği sorusunun önemini gitgide arttırmaktadır. Ayrıca, teknolojik çalışmaların ve inovasyonun günümüzde sektör içi bir çalışma oluşumundan, interdisipliner ve şirketler/gruplar arası bir yapı oluşumuna geçiyor olması firmaların, ortak çalışmaları gereken alan ve firmaları belirlemesi konusundaki bilgi ihtiyacını arttırmaktadır. Bu bağlamda da belli bir alanda çalışan ve inovasyon yapmayı hedefleyen bir kurum için çalışmalarını ileri götürmek için hangi teknolojilere yatırım yapması gerektiği sorusu günümüzde inovasyonun oldukça önemli problemleri arasında bulunmaktadır. Bunun yanısıra, patentler çok fazla veri içermesine rağmen bir alandaki on binlerce hatta daha fazla patenti istenilen amaçlar doğrultusunda etkin bir şekilde incelemek oldukça zordur. Özellikle metin tabanlı patent çalışmaları, aynı şekilde yazılıp farklı anlamlara gelen ya da çok farklı alanlarda birbirinden bağımsız işlevler için kullanılan terimler nedeniyle etkin bir çözüm sağlayamamaktadır. Bu çalışma ile CPC Patent Sınıflandırması kullanılarak belirli bir teknoloji içerisinde tanımlanmış patentlerin elde edilmesi ve sonrasında elde edilen verilerin veri madenciliği algoritmaları kullanılarak zenginleştirilmesi, analiz edilmesi ve Entropi ağırlıklı TOPSIS yönteminin uygulanarak patent verileri ve veri analiz algoritmaları ile çok kriterli karar verme yöntemleri kullanılarak Teknoloji Seçim Probleminin çözümüne yönelik objektif ve yenilikçi bir yöntem önerilmesi amaçlanmıştır.

Anahtar Kelimeler: Teknoloji Seçimi, Patent Analizi, Çok Kriterli Karar Verme, FP-Growth, Entropi ağırlıklı TOPSIS

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M****t U**r G***N

TEXT OF OATH

The study I presented as my Master of Science thesis titled ‘Technology Selection with Multi-Criteria Decision Making Methods and Data Analysis Algorithms Using Patent Data’ has been written without applying to any assistance inconsistent with the scientific ethics and traditions, and all sources I have benefited from were listed in bibliography and I have been used them by means of making references and I declare and confirm this with my honor.

01/11/2022

M****t U**r G***N

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LIST OF SYMBOLS AND ABBREVIATIONS

Abbreviations

OPS	Open Patent Services
R&D	Research and Development
FP-Growth	Frequent Pattern Growth
EPO	European Patent Organization
TOPSIS	The Technique for Order of Preference by Similarity to Ideal Solution
MCDM	Multi-Criteria Decision Making
AHP	Analytic Hierarchy Process
IP	Intellectual Property
CPC	Common / Cooperative Patent Classification
IPC	International Patent Classification
OPS	Open Patent Services
UNDP	United Nations Development Programme
INPADOC	International Patent Documentation
CQL	Contextual Query Language

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1. INTRODUCTION

The increasing pace of technological progress and the associated shortening of the life cycle of technological endeavors increases the importance of where, when and how much researchers and technology producing companies should invest. In addition, the shift of technical research and innovation from an intra-industry focus to an interdisciplinary and inter-company/group structure increases the information needs of businesses to identify disciplines and organizations with which to collaborate. In this context, it is crucial to research methodologies to track technological changes and create a decision support system to assess progress in areas of work, areas open for investment, areas of interest and potential collaboration sectors. This is because each of these variables can provide us with specific information about the future utility of an R&D effort. However, due to the high pace of progress, research based on direct market data is insufficient to develop insights into the future. This is because a firm with an innovative product on the market may have conducted and even completed R&D for many new products in the meantime. Decision-makers therefore need tools to determine the direction of technological progress beyond forecasts based on available market data.

As a consequence, firms and nations have begun adopting patent analysis-based future technology forecasting methods.(S. Lee, Yoon, Lee, et al., 2009) Patents not only offer legal protection for intellectual property rights, as well as specific details regarding the produced technology.(I. Park et al., 2014) Consequently, the forecasting of prospective technologies through patent research is essential for formulating management plans. It can be used, for instance, to reduce R&D spending in irrelevant industry sectors, to avoid loyalty payments demanded by unexpected technology infringements on competing enterprises, and to design R&D programs to secure core patents. (Y. G. Kim et al., 2008)(G. J. Kim et al., 2015) In other words, from the perspective of R&D decision-makers, patent analysis-based technology forecasting methods can provide valuable insights for enhancing a company's future competitiveness and serve as an essential tool for technology management decisions.(Ernst, 2003)

As explained in the literature section, when analyzing a dataset with a very large content such as patent data, it can be analyzed with many different methods. Although there are many studies on patent analysis, analyses based on comparing the number of patents corresponding to the searched terms constitute the majority of these studies. In addition, the methods chosen to analyze the patent data, which is completely technically based and has a high diversity due to the fact that it contains information from very different industrial sectors, are the most important factors in the accuracy of the results obtained from the research and the efficiency of the research.

Greenhouse Technologies stands out as one of the leading technological fields to show the developments in the field of agriculture and where agricultural technology can reach in the future, as it allows agriculture to be carried out in controlled environments. Therefore, identifying the technological areas that are important for the advancement of Greenhouse Technologies and enabling decision makers to identify these technological areas will be an important input in forecasting the progress of innovation not only for Greenhouse Technologies but also for the Agriculture sector in general. For these reasons, determining the direction of technological development in the field of Greenhouse Technology is one of the main objectives of this thesis and constitutes the case analysis part of the thesis.

Another reason for choosing Greenhouse Technologies as the case study of this thesis, which is explained in more detail in the following chapters, is the differences between patent data analysis methods. Because, in a word-based analysis study, searches with the phrases Greenhouse or Greenhouse technologies will quickly direct the researcher towards innovative studies on Greenhouse gases. However, these studies will not be directly linked to the main research topic of Greenhouse Technologies. At this point, as frequently seen in similar studies in recent years, the patent class defined for Greenhouse Technology will be used to determine the patent data set within the research by taking advantage of the fact that patents are classified according to their technological fields, which is one of the most important features as well as the data they contain.

As a result, for an organization working in a certain field and aiming to innovate, the question of which technologies it should invest in to take its work forward is among the most important problems of innovation today. In addition, Patent Data, which is the world's largest source of data on new technologies, has not yet reached a solution where it can be used efficiently to solve this problem. This study aims to enrich the information obtained by using data mining algorithms on patents separated by Patent Class for a field such as Greenhouse Technologies, which is unlikely to get the right answer with text-based studies in the patent system as mentioned above, and to bring an objective and novel proposal for the solution of this multi-criteria decision-making problem with an objective weighting using the Entropy-weighted TOPSIS method.

1.1. RESEARCH QUESTIONS

In line with the stated objectives, this study was conducted with the aim of finding answers to the following research questions.

1- Which technology should companies conducting innovation studies in a technology field choose to develop and strengthen in addition to their main technology areas in order to advance in their field?
2- Can patent data and patent analysis be used to solve this technology selection problem in studies aiming to achieve innovative outputs?

2. LITERATURE REVIEW

2.1. TECHNOLOGY SELECTION

Industrial managers are often faced with the challenge of selecting the most appropriate technology from a range of competing alternatives. The rapid growth, increasing complexity, and diversity of technologies has made technology selection a challenging process. Existing methods for technology selection are often narrowly focused on assessing the financial sustainability of available technology options or on traditional investment justifications. In many cases, selection procedures are based on decision support tools that are not well suited to technology selection.

Technology selection is an extremely important decision-making area for businesses. Rapidly changing technology and an ever-increasing number of technology alternatives cause businesses to face challenges in selecting the appropriate technology. At the same time, new technology applications for enterprises will provide opportunities for product diversification and new business ideas. Technology has been defined in different ways by different authors. While technology offers many opportunities to businesses, it also has some disadvantages. (Lei, 2000)

There is a rich literature on technology selection for R&D reasons. Similarly, various frameworks and techniques have been proposed for investment justification, and there are several literature sources on the subject. If the new technology has been sufficiently developed through all R&D stages and demonstrated at bench scale, pilot plant, and semi-commercial scale, it can offer significant capital and operating cost advantages. A joint development project with an appropriate technology partner or supplier can speed up the process and involve more resources and expertise. Understanding patent coverage will require a comprehensive review of the IP position. Increasingly complex and abundant technology alternatives have led businesses to search for a technology they can understand and use. To fulfill technological demands, businesses participate in diverse technology management techniques and implement technology strategy and planning.

This is getting more difficult as a result of the rising complexity of technologies; the convergence of technologies; the plethora of technological possibilities; the greater expense of technological development; and the faster dissemination of technologies.

In the research literature on technology selection, Chan et al. examined evaluation methods for technology selection and presented a sample method by applying fuzzy and non-fuzzy multi-criteria decision support systems methods for technology selection within the criteria they examined. (Chan et al., 2000)

Tuominnen and Torkkelli explained the importance of a company's core competencies and emphasized the importance of keeping these technological core competencies up-to-date on the sustainability, competitiveness, and R&D capability of the company. They suggest that decision-makers should base their technology selection processes on developing and reinforcing the company's core competencies, taking into account where and where a company is and where it needs to go from there. This is because a company's survival depends on the added value it generates through its core competencies and the competitive advantages that this value offers in the current market. (Tuominen & Torkkeli, 2002) So, it is very important to use the right tools and information to choose technologies that will improve a company's core competencies.

In their case study of the Near Zero Energy Building technology area, Salvado et al. developed an example of a decision support system with the help of multi-criteria decision making for the selection of technologies suitable for use in a specific area. They did not use a specific MCDM method in their method; instead they proposed a new system to rank the data they collected within the specified criteria. (Laguna Salvadó et al., 2022)

In his article, Öztaysı illustrated the problem of selecting the most appropriate technology for the development of a content management system and used the AHP-TOPSIS-Gray method, one of the MCDM methods, to rank the technologies identified in his study.(Oztaysi, 2014)

Wang claims that an enterprise's selection of technology has an impact on its investments in research and development. A wise technology selection will make full use of a company's resources and enable quick and effective marketing of the

developed product. Patent analysis of technology choice for company is the method by which patent analysts give decision-makers the most knowledge about technology history, technology forecasts, and prospects of technology development. It offers thorough technological research data. Wang proposes that a technology life cycle may be inferred from this data by examining the outcomes of patent searches and the number of patents obtained in specific fields during the selection of a timeline, and that this trend analysis can be a key indicator when choosing a technology.(Wang, 2012)

Shen et al. proposed the use of a hybrid method to perform technology selection in their study. Within the proposed hybrid method, they first found the patents that cite each other or cite the same source in a certain technological field, and then classified and prioritized the technologies in the OLED field by weighting the criteria they determined to rank these patents with the AHP method.(Shen et al., 2010)

2.2. EXPLAINING AND PREDICTING TECHNOLOGICAL DEVELOPMENT BY UTILIZING PATENT DATA

In today's society, intangible assets such as intellectual property rights and trademarks contribute significantly to a company's total net worth. Patents are one sort of intellectual property rights-related document. They are utilized to legally protect registered intellectual property, monopolized technology, and to provide a competitive edge to the firm. In addition, they create revenue through marketing, copyright, and licensing of intellectual property.

Patents, which can also be called registered research and development registration documents, represent a nation's or organization's technological progress. The creation of a patent requires an agreement between the patent owner and a government or government-designated organization. Performing a patent analysis can assist businesses in establishing the originality of their ideas as well as the intellectual property and technological capability of their competitors throughout the patent application or infringement investigation process. Patent Analysis not only improves the company's technological competitiveness, but also helps with the efficient use of intellectual property ideas, the growth of those ideas over a

specific period of time, and the determination of the advantages and disadvantages of monopoly rights in a more accurate and meaningful manner. Furthermore, patent analyses can provide extremely important information for anticipating future technological trends in a specific technology industry. Organizations trying to decide the path of their R&D research and produce a Technology Roadmap can benefit greatly from their use. In addition, patent analysis can provide extremely important data for anticipating future technical trends in a specific technology industry.

However, with Patent Analyses, organizations have a hard time trying to find, analyze, compare and classify patent documents and manual processes of examining, evaluating and explaining drawings, texts, claims and technical information, and they often have to do Patent analyzes blindly. Software solutions are needed to facilitate these analysis processes and to repeat them within determined scenarios and at certain intervals, and my research aims to inform researchers about how and which features a sample software solution should be made.

Innovation has emerged as an important process that drives technological development, as every moment of our lives, including the economy, is guided by Technology. Innovation, in other words, innovation studies can be considered as the seed of developments and researches in today's world, in the simplest terms, together with forming the basis of technological development. We need to take advantage of innovation, which is at such a fundamental point for our current technological and socio-economic development that progresses accordingly, in order to predict our development direction or development rate. So, how important is innovation in this process, and how can it determine this innovation process, which consists entirely of ideas, as a measurable and analysable commodity? One of the first to ask this question was Jacob Schmookler, and in his 1950 article, which was one of the first in its field, he discussed and examined the question of whether it is possible to obtain guiding information about innovation activities, technological process and technological change phenomena by using the data of the US Patent Office.(Schmookler, 1950) At the end of this study, which is quite ahead of its time, Schmookler stated that there are many data that can be useful in explaining the innovation progress in patents and that

these data can be useful in statistical measurements, but the nature of the invention, the cost of an innovation, the promotion and adaptation processes, which should be examined under the innovation term and innovation, He states that many factors that may be necessary to carry out a real study, such as the definition of technology needs, are not yet measurable and defined, and with the definition of these processes in the future, Patents are an important data provider.

In the process that lasted until the 1980s, it was not possible to carry out the studies envisaged by Schmookler due to the limitations of the technological developments of his time and the newly developing understanding of innovation. In the 1980s, Basberg and Griliches emerged as prominent representatives of a new understanding of the use of patents as a data source in their work based on Schmookler's work. Instead of interpreting patent statistics on the general economic situation, Basberg focused only on determining the development and progress of the Norwegian Whale industry and predicting probability for the future with his work in 1982.(Basberg, 1982) It has also been one of the main sources for many articles written. Griliches, on the other hand, referred to the great problem he saw in the inability to measure Innovation, which is now accepted as the engine of economic growth,(Griliches et al., 1986) and even described his discomfort in this regard with the following words of Lord Kelvin.

If you can measure, you are aware of what you are talking about, if you can also express what you are measuring in numbers, you now know what the quality you are measuring is, but if you cannot measure and cannot express it numerically, the information you have is insufficient and unsatisfactory; This information may be a starting point for the progress of scientific studies, but it is not clear how sure you are of this.

Analyzing patent data has long been seen as a crucial approach for evaluating various facets of technical development. The majority of studies have employed patent numbers as a method for examining the relationship between technical advancement and economic growth or evaluating the research and innovation process in a national or worldwide setting.(Griliches, 1998)(Crosby, 2000)(Paci et al., 1997) On the other hand, other studies have examined it from the perspective of company policy, utilizing patent statistics as a technology indicator

to determine how far technology has progressed in a particular industry.(Ernst, 1997b)

Patent analysis has also used as a foundation for analyzing a company's research and development, technological strengths and weaknesses of competitors.(Liu & Shyu, 1997)(Ernst, 1997a)(G. J. Kim et al., 2015) Since patenting abroad can be a lengthy and costly procedure, it appears logical to suppose that a corporation will only patent abroad if it is convinced that its products will have a sizable market in the country where it patents. It is well known that the quantity of patents filed by foreign corporations in a country is dependent on its technological level and patenting regime.(Bosworth, 1984)

Patents were utilized as a proxy for inventive and innovative activities in order to examine the interrelationship between industrial sectors and technology domains.(Gassler et al., 1996) Using patent data, patterns of innovative activity at the technological and national levels were also analyzed, and it was discovered that, while these patterns change consistently within technology classes, they are quite similar across nations.(Malerba & Orsenigo, 1996) As an alternative to patent counts, patent claims data has been investigated, and it was discovered that claims are a more accurate measure of national technological capacity.(Tong & Frame, 1994)

In order to examine in more detail the use of patent data in studies related to the identification and prediction of innovation and technological development, some literature studies are reviewed in a time sequence.

Griliches, Pakes and Hal stated which parts of the patents would be used and how to obtain usable data, in short, he stated that patents are an important data source not only in number but also in their content. However, of course, in accordance with the possibilities of the 1980s, it did not seem possible for them to carry out a study using all the information contained in the patent. It has been revealed that the data obtained from the patents and the patent outputs weighted in terms of quality will be important.(Griliches et al., 1986) Griliches continued his studies on the subject until the 2000s, with an article he published in 1996, on the use of patent data as an economic indicator. within the research; He stated that although obtaining data from patents is a difficult and laborious process, it is currently an

unrivaled source of information on technological progress, change and innovation.(Griliches, 1998)

They mentioned the importance of patents in technology predictions on a subject-based basis with the weighted average and counting systems they proposed within the scope of their study where Chen et al. examined Australian patents between 2000-2014.(Chen et al., 2017)

Christopher Benson and Christopher Magee see Patents as the most important source of big data regarding their Future Technology Foresight studies, and they state that consistent Technology processes can be predicted on selected subjects by using only the Patent data, with the Patent Technology Increment Indicator method, which they developed using the classification overlap method within their studies.(Benson & Magee, 2016)

Lee et al., based on the assumption that the patents filed in the European Patent Office, the United States Patent and Trademark Office and the Japan Patent Office for the same invention by the same applicant or inventor, called triadic patents, are more valuable and instructive than other patents. They aimed to use the data they obtained by searching according to their relationality according to the International Patent Classification (IPC) for technological prediction according to the weighted average.(W. S. Lee et al., 2015)

In their study, Kim and Bae took the method proposed by Lee et al. as an example, but they showed that using the methods they classify the patents belonging to a certain field based on the common patent classification (CPC) codes, usable results can be obtained for technology predictions. However, they stated that the method should be examined with other sectors and larger samples, since the sample they used was small and they only used the method for the health care sector.(G. Kim & Bae, 2017)

Park et al., using semantic analysis to analyze patents, aimed to develop an important matching method for possible interdisciplinary and possible joint R&D studies within the same discipline by matching the patents' keyword phrases and semantically.(I. Park et al., 2014) Although it seems to have reached appropriate results for simulations, the results do not work efficiently because they suggest market competitors as well as partnership opportunities. Although I will benefit

from this study in terms of semantic analysis in this study, the method will be to obtain vector data that I can use for machine learning from the relevant analysis results.

In his master's thesis presented in 2019, Mehmet Sezer proposed a technology intelligence tool that provides innovators with information about technological trends and the degree of innovation by revealing current opportunities and threats in order to capture innovations.(Sezer, 2019) While conducting this study, Sezer utilized a HUP-Growth algorithm that uses the co-occurrence frequencies of CPC codes in the technological field examined, together with the number of citations. The technology intelligence tool in this thesis was also analyzed with the article published after the related thesis.(Altuntas & Sezer, 2021)

There has been a recent uptick in the number of scholars who are recommending content-based patent intelligence solutions. Analysis of keywords is one of the methods that fall under the category of content-based approaches. Many academics have built keyword-based patent intelligence methods in order to locate new technical opportunities from patent gaps(S. Lee, Yoon, & Park, 2009), identify trends in high technology(B. Yoon & Park, 2004) and predict new technological concepts. Yoon and Park, as well as the creation of technology roadmaps(S. Lee et al., 2008; B. Yoon et al., 2008). The method of patent intelligence known as keyword-based patent intelligence makes use of occurrence information, which may include the frequencies of detected keywords and co-occurrences between keywords. In general, content-based approaches converts each patent into a key vector using the vector space model that is utilized in information retrieval(Salton et al., 1975). Next, it determines the similarities between patents utilizing similarity measures, such as Cosine similarity and Euclidean distance, and finally, it creates patent maps and patent networks. content-based approaches is restricted due to the fact that it is unable to cover fundamental technological concepts such as the purposes, uses, and structures of the relevant patent (Cascini & Zini, 2008)(Cascini et al., 2004)(J. Yoon & Kim, 2011). In spite of its ease of use and its simplicity, content-based approaches have this limitation. In addition, numerous studies have demonstrated that the frequency and co-occurrence of keywords in patents are unable to accurately

represent the inventive knowledge and method of patents that are related to one another (An et al., 2018)(H. Park et al., 2013)

There are further studies that seek to foretell future technical advancements by studying patents with a variety of data mining approaches. Association rule mining of international patent classifications (IPCs) for patent documents is used to identify potentially beneficial technical developments (Jun, 2011). In addition, the most promising areas of technology are determined by analysing variations in patent indicator values for each IPC over the course of time using association rule mining (Shih et al., 2010). Moreover, by applying network analysis to IPCs, the connections between technologies may be visually represented, and a conclusion can be made as to whether or not the technology is likely to be successful based on the centrality of IPCs and the distance between nodes(S. Park et al., 2015) . There have also been inquiries exploring the feasibility of forecasting the emergence of potentially lucrative new technologies using a text mining approach on an unstructured patent title and abstract. Text mining for Apple Inc. patents is a technique that may be used to identify potentially relevant unfilled market positions.(Jun & Park, 2013) Using the generative probabilistic model of latent Dirichlet allocation of renewable energy technology patents, more study was conducted to forecast vacant technologies. This was done to determine the likelihood of particular technology becoming outdated.(G. J. Kim et al., 2015) Obtaining patent keywords and then applying generative topographic mapping as a probabilistic reformation of a self-organization map were the methods used in another study that examined technical landscape gaps and the possible advantages associated with such gaps.(Jeong et al., 2015)

Methods of unsupervised machine learning have been increasingly popular in recent years, particularly for the goal of condensing patent data dimensions and mapping them into a two-dimensional space to enable visualization. Because text data are often converted into numeric vectors so that the frequency of a word in a document can be assessed, these requirements become even more urgent when analyzing the description sections of patent filings.(Choi et al., 2021) This is because the frequency of a word may be quantified. Using a self-organization feature map, Yoon et al. mapped patents that were comparable in terms of their technological content onto a two-dimensional space. (B. U. Yoon et al., 2002)

Similarly, Lee et al. used principal component analysis to illustrate technology vacuums, which are sectors that receive comparatively less attention, and presented these technology vacuums as potential new technical possibilities.(S. Lee & Park, 2005) Several studies have utilized additional data-mining techniques to bibliographic patent data in order to examine the relationships between other types of patents or other technical domains. For example, Kim et al. employed association rule mining to analyze often co-occurring technical areas (i.e., international patent categorization) in patents in order to acquire a deeper knowledge of the variables that lead to the emergence of convergent technologies. Choi et al. and Jun et al. applied cluster analysis to arrange patents into groups based on their shared characteristics. In reality, the development of these data-mining techniques has contributed significantly to the breakthroughs in patent analysis.

2.3. GREENHOUSE TECHNOLOGY

Agriculture is definitely the most affected by the world's increasing environmental challenges. As a result, new technology has begun to contribute to agricultural technology. Agriculture productivity has increased as a result of technological advancements, while agricultural harm has decreased.

When it comes to innovative agricultural technologies, greenhouse production is definitely the most prominent. The primary reasons why greenhouse farming is favored are higher agricultural output, reduced climatic impact on agriculture, and less environmental damage. According to data, interest in greenhouse agriculture has surged more than ever in the last decade. Many universities and scientific research organizations throughout the world have begun to make significant expenditures in this subject, recognizing that agriculture provides the majority of human nutritional needs.

Greenhouse Technology, in conjunction with automation, is the process of producing favorable environmental factors for plants or crops. While it is primarily used to protect plants from adverse climatic conditions, it has evolved to deliver increased yields as well as lower labor and resource costs. Greenhouses are simple to manage because they are self-contained environments. Commercial growers today have a wide selection of technologies at their disposal to ensure

maximum output with the least amount of effort. While it is commonly known that greenhouse cultivation decreases reliance on soil and is less affected by climatic variables, modern greenhouses have also made soilless agriculture possible. The ingredients required for plant development are not incorporated directly into the soil using modern technology. Instead, the nutrients required by the plant are presented as solutions in locations where the plant roots come into touch. Methods like as hydroponics, aeroponics, and aquaponics are among the most popular methods of soilless agriculture production. Agriculture can be carried out using these approaches, particularly in urban settings, and chemical damage to the soil can be reduced.

In addition to all these, Greenhouses have become a development and testing ground for many agricultural developments before they are used in the field or in another environment thanks to their controlled production opportunities. One of the studies on this subject is the work of Mohammadian et al. on prioritizing the use of IOT technologies in agriculture. According to the results they obtained using the fuzzy-TOPSIS method within this research, Greenhouse Technologies take the first place among other agricultural technologies. (Mohammadian et al., 2020)

Aznar Sanchez et al. conducted a bibliometric and content survey of scientific research on greenhouse technologies in the Elsevier-Scopus research database to examine global research trends in Greenhouse Technology. They applied content-based data analysis methods on the content of the scientific articles they obtained to differentiate important institutions, people and topics in the field. As a result of this study, the three most important areas of greenhouse technology are irrigation technologies, microclimate technologies and soil conditioning technologies. Since the study is based on scientific articles, it is not a needs analysis, but rather based on the predictions of researchers in the field.(Aznar-Sánchez et al., 2020)

In the study carried out with this thesis, thanks to the Patent analysis, the studies of the people and institutions working in the field of Greenhouse Technologies were focused on and the analysis was carried out in this direction.

3. MATERIAL AND METHOD

3.1. PATENT DATA

A patent is simply an agreement between the government and the inventor of an invention. Those who want to use an invention or get a patent are obliged to read the patent claims, which are the most significant component of a patent and include the legal language. These claims define the application of the innovation. By utilizing the patent application's description and drawings, the claims put this objective into sharper perspective. The patent claims are the most important part of a patent application because they establish the breadth of the monopoly or exclusive right that a patent grants to its owner. In actuality, there may be only one sentence in patent claims that grants a corporation a monopoly in a particular field of technology and provides the corporation with long-lasting economic benefits. It is therefore of the utmost importance to conduct exhaustive research and scrutiny of patent claims. The claims section of a patent often appears at the very end of the document and contains one or more statements that define the scope of protection provided by the patent or patent application. Patent attorneys and inventors evaluate the claims of previously granted patents to determine whether a possible innovation can be protected by a patent and whether a patent has been infringed. The wording of patent claims is of the utmost importance when submitting a patent application or litigating a lawsuit alleging patent infringement. Despite the fact that manually comparing the claims in one patent with the claims in a number of other patent documents is a time-consuming operation, it is extremely important due to the abundance of available information. As a result, patent analysis can be accomplished in a substantially shorter amount of time due to the availability of tools that facilitate a more thorough study of patent claims and automate the process of conducting patent analysis.

Other key advantages of patent analysis include helping to identify how patents can be used as financial assets, generate license fees, and even give a company a competitive advantage. The ever-increasing amount of patent information has made the responsibilities of patent research and analysis crucial, both legally and

administratively. As a result, patent data is evaluated in various ways for various purposes. For example,

1. Determination of innovation in patents,

2. Analyzing patent trends,

3. To predict technological developments in a particular field,

4. Strategic technology planning,

5. Examination of patents for the detection of infringement,

6. Determination of patent analyzes for R&D needs,

7. Identification of promising patents,

8. Technology roadmap,

9. Identification of technological shortcomings and hotspots

10. Identifying technological competitors. (Abbas et al., 2014)

And in similar fields, organizations and other institutions can benefit from patent data and analysis. Patent analysis not only uncovers current technical trends, but also helps R&D policymakers predict future developments and identify potential competitors. Technology Roadmap is another effective application of patent analysis tools to assist R&D work for strategic technology planning. A Technology Roadmap is a process used to assist a business's strategic research and development tasks in order to match technological advancements with product evolution and market potential. And on patent analysis, it is a method used to classify the analysis data obtained in this study and to make predictions for the future.

The European Patent Office's patent data will serve as the primary data source for this investigation. Patents are a sort of intellectual property with private and monopoly rights, and they are often illustrative, publicly published documents that are registered by countries and international organizations. Patents are one of the most comprehensive sources of information about technical advancement, and they also contain information that cannot be accessed elsewhere. Patents are thus the "big data" source most strongly associated with future-proof technology

assessments (FTA). The European Patent Office also grants access to processed and unprocessed patent data to researchers who have obtained the required work permits. This study is based on the evaluation of the fundamental information, values, and technological advantages of patent papers in a specific field in comparison to the exemplary R&D studies offered in the exemplary study areas. In addition to patent data, country and regional R&D indicators released by organizations such as the European Union, UNDP, and Turkish Statistical Institute will be utilized to strengthen the location-based impact of the analysis. The methodologies of data analysis, natural language processing, and machine learning will be utilized for this goal.

It will be a very important input for us to be able to analyze, follow, and make sense of product-based, sector-based, or country-based innovation studies on the basis of data. This ability will provide an advantage for economic development and help us better understand how our lives are influenced by technology. When viewed in this light, analysis of innovation data based on patents emerges as the strategy that is both the most effective and the most efficient in making sense of the data. Because patents have been meticulously documented over the course of the past century, we can use them as valuable resources to track the development of innovation studies in various industries, geographical regions, or countries at a particular point in time. This can be done on the time plane as well as the horizontal plane. However, the registration method of patents and the information/different information fields that they contain, as in previous studies, are only examined by the analysis to be made on the class (IPC - CPC) or title name, or on a relatively small number of patents compared to the total, within these researches the original information of the patents, which results in the inability to use its thesis. For this reason, in this study, it is planned to perform semantic analyzes on patent claims and summary information, as well as analytical classifications such as class, inventor, patent family. In addition, instead of extracting data from patents created as a ready-made system or pdf, more accurate estimation and identification studies will be carried out by providing access to a much wider patent pool with the program to be developed within the research by using the OPS (Open Patent Services) tool of the European Patent Office directly.

In addition to the analyzes to be made, it is aimed to develop a decision support system that can present basic comparisons and recommendations with this study. Because Patent data only gives information about innovations on a product. However, since the importance and impact of each of these patents is not the same, purely patent-based analyzes cannot fully reflect the current situation in many cases. It only provides basic vector information about the direction that technology can go. However, it will be possible to reach much more accurate analyzes if the relevant patent data are supported by data such as Innovation Scorecard, project acceptance information, export-import information. By obtaining clean and interrelated data, it will be possible to develop artificial intelligence systems that can reveal basic inferences and information nodes on the data with Machine Learning methods. In addition, it is aimed to create recommendation information for experts by analyzing these analysis data with the techniques within the Multi-Criteria Decision Support Systems.

In this context, within the scope of the research methods to be applied, primarily descriptive and relational research methods, which are among the quantitative research methods, will be used by using data analysis and statistical methods of the obtained patent data. However, in the further process of the research, Multi-Criteria Decision Analysis methods will be used in the development of the decision support system. Multi-Criteria Decision Analysis methods examine and organize the collected statistical data according to the expert opinions to be collected and seek an answer to the question of why. For this reason, in the second part of the research, qualitative research methods will be used as well as quantitative methods.

Open Patent Services, often known as OPS, is a company that offers online services for machine-to-machine inquiries and delivers data on production-ready patents from the European Patent Office (EPO).

3.2. DEVELOPING AN APPLICATION TO GATHER PATENT DATA

Since a considerable length of time, patent information has been employed largely for patent document and patent clearance searches. There have also been prior art searches and infringement searches among these sorts of investigations. The goal of doing a patent search is to identify patent papers that cover an invention

believed to be most comparable to the desired technology. As a result, the guiding principle has been to construct the search procedure such that it sorts the shortest possible list of patent papers. Searchers are needed to analyze the sorted patent papers to evaluate if they may be used as evidence to contradict the uniqueness or creativity of an invention, or to demonstrate whether an invention infringes upon the patent documents that cover other innovations. Despite the fact that a patent document provides a considerable quantity of information by nature, it is possible to adopt unique methods by employing many patent documents simultaneously. These revolutionary procedures might provide new knowledge that would be unavailable in any other setting. A method that assesses patent papers based on the passage of time is one example of such a technique. In this method, at some point you will cease removing relevant patent documents from the search and instead examine a cluster of a certain number of patent papers in the order in which the patent applications were filed. This may provide the appearance that one has actively participated in the development projects, allowing one to observe how far technological progress has come. A further example of this would be a strategy that emphasizes the personal information in patent documentation, such as the rightholders and inventors. In this technique, the collected patent papers are sorted based on the company, and then compared. This gives insight into the various corporate technology development efforts and strategies. This way of comprehending patent information as a group (or cluster) is the core concept of patent mapping, and it leads to the production of new information.

There are several websites on the Internet that provide access to patent papers. However, some of these sites are subscription-based and others restrict access to the first 500 results on their web pages. This study utilized the INPADOC database and the OPS internet service in order to gain access to patent papers online for free. The European Patent Office updates INPADOC every week. (European Patent Office, 2022)The International Patent Documentation File (INPADOC) is a worldwide repository of bibliographic and legal status data. The INPADOC database is created by the European Patent Office (EPO), developed by the editorial team at FIZ Karlsruhe, and is available on STN in two upgraded versions: INPADOCDB, where each record represents a patent application, and

INPAFAMDB, where each record represents a global patent family.(FIZ Karlsruhe, 2019) The INPADOC database receives patent information from patent authority gazettes, registries, web services,(European Patent Office, n.d.) and through these sources, information from over 100 patent authorities is uploaded to this database. (Lingua, 2005)

This database has become essential for academic research, commercial assessments, accessing patent data, and determining the status of patent protection due to its astounding variety of legal case data. The European Patent Office gives access to the INPADOC database and is comparable to the ESPACENET database. ESPACENET provides free worldwide access to information about innovations and technological breakthroughs from 1782 to the present. This database is updated daily by specialists and contains information on over 110 million patent papers worldwide. In the study, the European Patent Office database (OPS) internet service was utilized to collect data through a software application. OPS is an online service that offers data access.

For the purposes of the research that fall under the purview of this thesis, an attempt was made to observe and predict the innovation progress in a specific area with the patent data by conducting research at certain stages with the API developed to connect to the OPS system. This was done in order to satisfy the requirements of the research that fall under the purview of this thesis.

In this context, a software in Python language has been prepared to obtain the needed patent data for use in this thesis, taking advantage of the experiences I have gained within the Informatics Master's program at Ankara University.(Gocen, 2022)

One of the most important features of the software application is that it can connect to the OPS system via the relevant API and perform search queries in accordance with CQL language.

CQL, or Contextual Query Language, is a standardized query language for databases established by the Library of Congress. CQL is a formal language that can be used to express queries for information retrieval systems, such as online directories, bibliographic catalogs, and museum collection information. It was developed to facilitate searching and retrieving data from databases over Internet

connections. The objective of query design is to ensure that queries can be read and written by humans, have a natural flow of thought, and preserve the expressive potential of more complicated languages. A CQL query may have a single search clause or many search clauses joined by boolean operators. It could be a sort specification followed by 'sortBy' keyword. It may also contain prefix assignments that provide context set identifiers with abbreviated names.(The Library of Congress, 2013)

CQL allows us to perform many queries such as query language, text-only fields, year-based or classification-based searches. As an example of a search using CQL, if we want to search for the terms precision agriculture and smart agriculture in all patent text fields for patents between 2016 and 2021, the CQL query to be written will be as follows.

(ftxt = "precision agriculture" OR ftxt = "smart agriculture") AND pd within "2016,2021"

Although the software can be used to analyze the INPADOC patent database, the efficiency of the software is also limited due to the following limitations of the EPO-OPS system.

1- In the queries made from the OPS system, a maximum of 100 patent data can be retrieved each time.

2- In OPS system connections, a maximum data retrieval size limit of 1 mb per minute must be observed.

3- The OPS system allows a maximum of 4gb of data transfer per week in free use for researchers.

Due to these constraints, the operation of the software is organized to divide the queries into small packages of maximum 100 patents in many cycles and to comply with the data transfer rate determined for each minute.

3.3. FP GROWTH ALGORITHM

Association rule mining identifies relationships between dataset objects. It identifies links, correlations, or causal patterns between things or groups of objects in huge datasets, database systems, and other data registries. To extract

an association rule, a transactional database is necessary. Each transaction also provides a list of products. As a result of the growing significance of association rules, numerous algorithms have been developed, and, as with all new algorithms, association algorithms have continued to advance by being modified in accordance with industry requirements.

Due to its speed and low cost, the FP-Growth algorithm has become one of the most extensively used algorithms in association rule mining today.

FP-Growth is a method for discovering recurring patterns. This algorithm has been demonstrated to be more cost-effective than the majority of its predecessors. This is mostly because the frequent pattern tree (FP-Tree) retains the entire database in a compact and dense data structure. In FP-Growth, unlike Apriori-based algorithms, the complete database is only examined twice. The first is used to calculate the support value of each item, while the second is used to construct the tree structure. FP-Growth is advantageous for large datasets since it reduces the need to continually generate new candidates and search the database.

In the initial step of the FP-Growth algorithm, the database is scanned once and the support value of each item is calculated. The items whose support values are greater than or equal to the algorithm-assigned support threshold value are listed in decreasing order. Similarly, the elements within each database transaction are ordered in descending order by their support value.

To establish the frequent pattern tree, a new node with the name root must first be created. Then, each transaction is inserted in the tree according to its item order. If an item in the dataset is missing from the tree, a new node is generated and its support value is set to 1. Support values are also maintained for each item. Only the support value of the node is increased by 1 if the item has already been created. Additionally, a header table is maintained to maintain the link between nodes. In this table, each node's origin is indicated. At the same time, pointers are used to connect the same nodes in the tree. Following the completion of the tree-building procedure, the Fp-Growth algorithm is applied to this structure, beginning with the least common item. Determine the paths along which the item occurs. Within each path, the item's support value is assigned as the path's support value. These pathways constitute the conditional pattern's basis for this item.

From each conditional pattern base, a conditional conditional pattern tree is generated. The procedure is then applied in a recursive manner to this conditional pattern tree. This procedure is performed for each item in the table, so determining the collection of frequent items. The FP-Growth Algorithm permits the main work to be subdivided according to the divide-and-conquer strategy.

3.4. ENTROPY WEIGHT METHOD

The concept of entropy was defined by Rudolph Clausius as a measurement of uncertainty and disorder within a system. This concept was later adapted to information theory by Claudie E. Shannon. In information theory, entropy is defined as the measurement of uncertainty in information in terms of probability theory. The basic idea of the entropy method is that this information comes from the clustering value between data. The method has a significant advantage in measuring the weights of criteria by providing an objective contribution to the solution of decision-making problems rather than subjective information. According to Information Entropy, the quantity and quality of information available is the most important determinant of the accuracy and reliability of the decision to be made in a decision-making problem. In this context, the Entropy Weight method has been used to measure the amount of useful information provided by the available data. In short, the entropy method measures the amount of useful information provided by the available data. Accordingly, the objective weights of the criteria are determined by the "contrast density", i.e. how far apart or different the alternatives are in value with respect to each criterion. The more intense this contrast is, the more information is covered and conveyed by the relevant criterion. Or, conversely, less. For example, if all alternatives for a criterion have very similar outputs, it is assumed that the relevant criterion will not have much of a function in making a decision. It is even assumed that a criterion for which all outputs are equal can be completely removed from the decision-making situation.

One of the most important reasons why the Entropy weight method is a good choice for making decisions with multiple criteria is that it lets the importance weights of the criteria be calculated objectively, without relying on the personal judgments and opinions of experts.

The steps of the entropy method are explained:

1- Normalizing the decision matrix to ignore irregularities with different evaluation entities and ratios is the original decision matrix;

$$P_{ij} = \frac{X_{ij}}{\sum_{i=1}^{m} X_{ij}} \tag{3.1}$$

2- Then the entropy value for each criteria is found by the equations given below.

$$e_j = -k \sum_{j=1}^{n} p_{ij} \ln(p_{ij}) \tag{3.2}$$

$$k = (\ln(m))^{-1} \tag{3.3}$$

3- Deviation values are obtained for each criterion by the following equation.

$$d_j = 1 - e_j \tag{3.4}$$

4- Finally, the weight value to be used in weighting the deviation values is calculated.

$$w_j = \frac{1 - e_j}{\sum_{p=1}^{n}(1 - e_p)} \tag{3.5}$$

3.5. TOPSIS METHOD

The multidimensional weighting method with ideal points (TOPSIS - Technique for Order Preference by Similarity to Ideal Solution) is an approach developed by Hwang and Yoon for multi-criteria decision making problems, which is used to determine the order of preference of alternatives and provides a more comprehensive comparison than other methods. The method is based on selecting the alternative with the shortest distance to the positive ideal solution and the

farthest distance to the negative ideal solution. The TOPSIS method has the advantages of clear logic, simple calculation processes, allowing the best alternatives to be determined in the light of criteria, and the importance of criteria can be included in the analysis. Therefore, it can be used to model selection and ranking problems in many sectors.

TOPSIS recognizes that each criteria has a tendency of increasing or decreasing utility. Therefore, it is easy to identify the ideal solution and the negative-ideal solution. The positive ideal solution is based on a solution that tries to maximize the utility criteria while minimizing the cost criteria. The negative ideal solution is defined as the solution that tries to maximize the cost criteria while minimizing the benefit criteria.

Steps of TOPSIS application:

1- First, the decision matrix is prepared. The decision matrix is an i x j dimensional matrix created by the decision maker after determining the decision options and evaluation criteria. Here, i and j are the number of decision options and evaluation criteria respectively.

2- Then, to create the normalized decision matrix, we calculate the elements of the decision matrix according to the following definition. The normalized decision matrix is obtained by taking the square root of the sum of squares of the values of each criterion of the decision matrix (sum of squares of the column values) and dividing the relevant element of the column by this value. If the value of any element of the decision matrix is 0, the value of the relevant element in the standard decision matrix is also 0.

$$a_{ij} = x_{ij} \Big/ \sqrt{\sum_{i=1}^{m} (x_{ij})^2} \quad (1 \leq i \leq m, 1 \leq j \leq n) \tag{3.6}$$

3- After normalization, the weighted normalized - standard decision matrix is obtained by multiplying the elements of each criterion in the decision matrix by the weight coefficient. This reveals the prioritization aspect of

the TOPSIS method in the decision-making phase. This is because weighting is done according to the importance of the criteria. The elements of the normalized matrix are multiplied by their respective weight values to form a weighted standard decision matrix, V . In this respect, in this research, the Entropy method, which is one of the objective weighting methods, will be used for weighting the criteria.

$$V = \left(a_{ij}^{*} w_j\right) \ (1 \le i \le m), 1 \le n) \tag{3.7}$$

$$\sum_{i=1}^{n} w_j = 1 \tag{3.8}$$

4- Positive and negative ideal solutions are calculated according to the formula below. Using matrix V, the sets of positive ideal and negative ideal solutions are obtained for each criterion according to the objective of the evaluation criterion of interest. If the evaluation criteria are in terms of benefits, the positive ideal solution is the largest values of the columns of matrix V and the negative ideal solution is the smallest values of the columns of matrix V. If the evaluation criteria are in terms of costs, the positive ideal solution is the smallest values of the columns of matrix V and the negative ideal solution is the largest values of the columns of matrix V.

$$V^{+} = \{v_1^{*}, v_2^{*}, \dots, v_n^{*}\} = \{\left(Max\ v_{ij} \middle| j \in J\right), \left(Min\ v_{ij} \middle| j \in J\right)\} \tag{3.9}$$

$$V^{-} = \{v_1^{-}, v_2^{-}, \dots, v_n^{-}\} = \{\left(Min\ v_{ij} \middle| j \in J\right), \left(Max\ v_{ij} \middle| j \in J\right)\} \tag{3.10}$$

5- The separation values to the positive ideal and negative ideal solution values are obtained. The Euclidean approach is used to find the deviations of the evaluation criteria from the positive ideal and negative ideal solution values for each decision option. The separation values are obtained as defined by the formula below. As a result of this step, separation values are calculated for the number of decision options.

$$S_i^+ = \sqrt{\sum_{j=1}^{n} \left(V_{ij} - V^*\right)^2} \quad (1 \leq i \leq m\,, 1 \leq j \leq n\,) \qquad (3.11)$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} \left(V_{ij} - V^-\right)^2} \quad (1 \leq i \leq m\,, 1 \leq j \leq n\,) \qquad (3.12)$$

6- The relative closeness coefficients to the ideal solution are calculated. The distances of each decision option from the positive ideal and negative ideal solution values are used to calculate the relative closeness coefficients to the ideal solution. Relative closeness values are calculated for each decision option with the distance formula given below.

$$C_i = \frac{S_i^-}{S_i^+ - S_i^-} \quad (1 \leq i \leq m) \qquad (3.13)$$

The formula calculates the share of the distance to the negative ideal solution in the total distance. As a result of the calculations, decision options with a C value close to 1 are prioritized. Finally, by ranking the criteria according to the calculated C values, a ranked list of the preferred criteria will be created as a result of the TOPSIS application.

4. RESULTS

4.1. ACQUISITION, ORGANIZATION AND CLEANING OF THE DATASET

Research studies start with obtaining patent data. In order to obtain this data, which will constitute the raw data of the research, it was necessary to first determine the query that best defines the field of research and to use the computer software prepared as described in the methods section for patent analysis. For the technology selection study in this thesis, the most appropriate query methods were investigated in order to access the patents within the Greenhouse Technology field, which was determined as an example. In this context, the results obtained with text-based query methods showed that there are patent data on greenhouse gases and related technologies as well as greenhouse technologies. For this reason, the need to use patent classification, which is an important power of patent databases, rather than text-based searches in this and similar patent research studies comes to the fore. This is because patents are classified by specialized patent offices according to their content and the technology fields they contain during the application and examination stages, and thus it is possible to access patents in the targeted technology fields much more accurately. In this classification area, the Cooperative Patent Classification (CPC) system, which is relatively newer and more detailed than other systems, is utilized. In this context, the research study started with determining the CPC code reflecting this field in order to access patents in the field of Greenhouse Technologies. In this context, a patent search was performed with the Y02A40/25 class over EPO OPS using our patent search software. Within the CPC, technology classifications are made according to their functions, and technologies are defined in lower and upper classes in this context.

In this context, the equivalent of the Y02A40/25 class is defined as " GREENHOUSE TECHNOLOGIES". In this classification system based on function, the neighboring classes of Greenhouse technologies include technologies such as water and soil control and conservation, seed and other agricultural technologies.

As a result, for the patent data acquisition studies to be carried out in the field of greenhouse technologies, patents belonging to the "Y02A40/25" class were extracted from the OPS system with the patent data acquisition software. However, for the patent analysis, the date range of January 1, 2001 - December 31, 2021 was determined in order to prevent errors that may arise from half a year within the year 2022 and to limit the data set with up-to-date information. In order to extract patent data with the software, an automatic query cycle was prepared and the software was run in such a way that each query would request less than 100 patents and would extract patent data on a monthly basis starting from January 1, 2001, and in months with more than 100 patents, it would go to partitioning within the month.

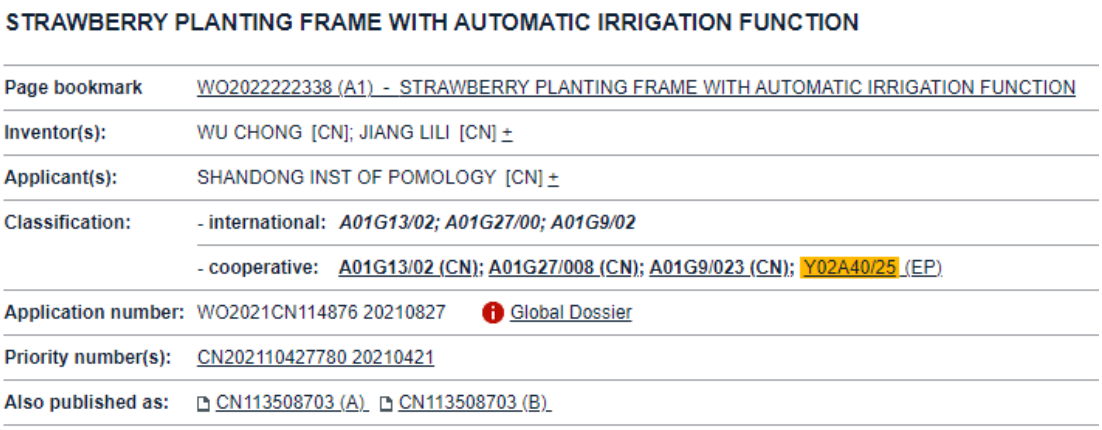
At this stage, a total of 67,506 patent data were downloaded as raw data set. To download these patents, the software ran a total of 872 queries on OPS. The downloaded data were first listed in the database within the software and sorted in date order before the data cleaning application.

Within this raw patent data, we first need to do a data cleaning. Within the collected data, we need to separate the data that does not have the necessary parameters or is missing identifying information and cannot be processed within our analysis from this raw data mass. Therefore, we need to start by identifying the patents that are necessary to perform the targeted analyses. When a preliminary examination of the raw data obtained is made, since the INPADOC database system is a database where all legal data of patents are kept, some patent files may contain missing information, especially due to the fact that there are patents that have been applied for recently and not all information has not been entered, and patents with incomplete or different data in some Far Eastern countries and utility model-like patent classes in Turkey. For these reasons, we first determined the criteria that we will look for patent documents for analysis. An example of a patent bibliography is shown in Figure 4.1. If we list these criteria;

1- The patent must have a title and abstract and this must be entered into the system. This indicates that the application of the patent has been completed and is in the process of completion and has been selected because it is a criterion.

2- The patent has an applicant. Since the data of the patent applicant company is also utilized in patent classification and ranking, this criterion was determined because it is not possible to use patents that do not have this information within the study.

In this respect, the number of patent lists decreased to 59,257 after the patents without abstract, title and applicant data were removed from the list.



STRAWBERRY PLANTING FRAME WITH AUTOMATIC IRRIGATION FUNCTION

Page bookmark	WO2022222338 (A1) - STRAWBERRY PLANTING FRAME WITH AUTOMATIC IRRIGATION FUNCTION
Inventor(s):	WU CHONG [CN]; JIANG LILI [CN] +
Applicant(s):	SHANDONG INST OF POMOLOGY [CN] +
Classification:	- international: ***A01G13/02; A01G27/00; A01G9/02***
	- cooperative: A01G13/02 (CN); A01G27/008 (CN); A01G9/023 (CN); Y02A40/25 (EP)
Application number:	WO2021CN114876 20210827 Global Dossier
Priority number(s):	CN202110427780 20210421
Also published as:	CN113508703 (A) CN113508703 (B)

Figure 4.1An example of a patent bibliography

In the second stage of data cleaning, the CPC classes were started to be studied. The main objective of the research was to make technology selection for future studies for individuals and organizations working in the field of Greenhouse Technology. Therefore, the main point that was taken into consideration while analyzing the patents was which technologies were seen in patents on Greenhouse Technology in addition to Greenhouse technology. As a result, the research question related to this topic was, "Which technology should companies that carry out innovation studies in a technology field choose to develop and strengthen in addition to their main technology fields in order to advance in their fields and to get innovative outputs, and can patent data and patent analysis be used for this choice?".

In this context, among the patents listed, patents that have only and only Y02A40/25 class as a single CPC value will not need to be processed since they do not offer us a new area for technology selection. For this reason, patents that only belong to CPC class Y02A 40/25 were also removed from the patent list.

After this process, the total number of patents in the patent list decreased to 31,040 patents. With this final data selection process, the patent dataset was finalized before data analysis.

4.2. DATA ANALYSIS

With data analysis - data mining algorithms, it is possible to examine the data within our raw data stack from different aspects. In this research, data mining algorithms are utilized to investigate the associations and interconnections between CPC codes within the patent list obtained.

In this context, the FP-Growth algorithm is used to investigate the frequency of occurrence and interconnectedness among a total of 280,809 CPC codes belonging to the patents in the raw data list.

Our main objective in this thesis was to identify other technologies used in addition to the Greenhouse technology and to select the most advantageous ones among these technologies. In this context, first of all, the FP-Growth algorithm was used to determine the frequency of co-occurrence of the identified patents in CPC classes and their support. Finding frequent itemsets and generating strong association rules from frequent itemsets are the two steps in association rule mining.

The Apriori Algorithm and the FP growth algorithm may be used to find frequent itemsets However, Apriori algorithm creates all itemsets by scanning the whole transactional database. The FP growth algorithm, on the other hand, only creates frequent itemsets based on the minimal support specified by the user. Because Apriori scans the whole database many times, it consumes more resources, and the time required to construct the association rules grows exponentially with the size of the database. On the other hand, the FP growth method does not scan the entire database several times, and the scanning time rises linearly. As a result, the FP growth algorithm is substantially quicker than the Apriori approach.

With this algorithm, the most common CPC classes and CPC class pairs in our patent data were determined. In order to solve the associations with the FP-Growth algorithm, the code block prepared within the Data Analysis software prepared on Data Collection is used. The piece of software required for this was

written in python language using FP-Growth and Panda libraries and made ready for use.

As a result, the FP-Growth algorithm will be applied on the column containing CPC codes of the data set table remaining at the end of the data cleaning study, and the frequency of occurrence and confidence frequencies of CPC codes within the data set will be determined.

In order to better explain this data analysis using CPC Classification codes, the CPC system must first be explained. The Cooperative Patent Classification (CPC) is a patent classification system developed in cooperation with the European Patent Office and the United States Patent and Trademark Office. The CPC is one of the patent classification systems that can provide researchers with the most information about the technology and features contained in patents, as it can define more than 250,00 categories.

In CPC codes, each phrase in the categorization is represented by a symbol, such as "Y02A40/25" (which represents "GREENHOUSE TECHNOLOGIES"). The initial letter is what's known as a "section sign," and nine sections of CPC is given at Table 4.1

Table 4.1 The nine CPC sections

The nine CPC sections	
A	Human necessities
B	Performing operations; transporting
C	Chemistry; metallurgy
D	Textiles; paper
E	Fixed constructions
F	Mechanical engineering; lighting; heating; weapons; blasting engines or pumps
G	Physics

H	Electricity
Y	General tagging of new technological developments; general tagging of cross-sectional technologies

After this, a number with two digits will follow to complete the "class symbol." The "subclass" will be defined in the next letter. The subclass is then followed by a number ranging from one to three digits that constitutes the "group" number. After that, there would be an oblique stroke followed by a number with at least two digits that represents a "major group" or "subgroup." A classification will be given to the patent application or other document at the most detailed level that is appropriate to the contents of the document by a patent examiner.

As mentioned, CPC codes provide very detailed information for patent identification as they are defined in great detail and hierarchically in sections, classes and groups. However, the use of full CPC codes in studies on relationality makes it very difficult to establish the relevant relationships. For this reason, the CPC codes collected in this analysis are redefined at the Group level and subgroups are ignored. An example of the partitioning of a CPC code is shown in Figure 4.2.

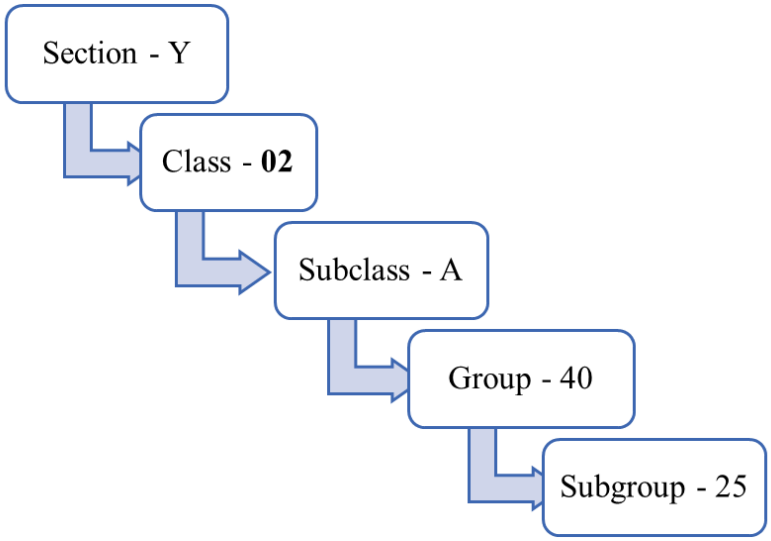


Figure 4.2 CPC segmentation of a sample CPC code (Y02A40/25 for Greenhouse Technologies)

After adjusting the CPC granularity, the FP-Growth algorithm was applied. As a result of FP-Growth, CPC group codes with a support level, i.e. a frequency of occurrence above 0.02, are given in Table 4.2

Table 4.2 Frequency of occurrence of CPC codes

Rank	CPC Codes	Occurrence Frequency
1	A01G9	0,751353
2	Y02P60	0,397487
3	A01G7	0,128673
4	A01G31	0,087758
5	Y02E10	0,058344
6	A01G13	0,052126
7	Y02A20	0,050387
8	Y02B10	0,032152
9	A01C23	0,029671
10	G06Q50	0,029285
11	A01G22	0,028608
12	B32B27	0,028093
13	A01G27	0,027738
14	A01G25	0,026095
15	C08J5	0,023518
16	E04D13	0,023293
17	E04B1	0,020651

Table 4.2 shows that two CPC codes in particular, "Cultivation in receptacles, forcing-frames or greenhouses" and "Technologies relating to agriculture, livestock or agroalimentary industries" are used more frequently in the patents in the dataset compared to other codes. The difference in the frequency of occurrence between CPC codes can be seen more clearly with the help of Figure 4.3

Below are the definitions of the CPC group codes listed in Table 4.3

Table 4.3 Definitions of the selected CPC group codes

No	CPC Group Codes	Defination of Code
1	A01C23	Distributing devices specially adapted for liquid manure or other fertilising liquid, including ammonia
2	A01G13	Plant Protection
3	A01G22	Cultivation of specific crops or plants
4	A01G25	Watering gardens, fields, sports grounds or the like
5	A01G27	Self-acting watering devices
6	A01G31	Soilless cultivation, e.g. Hydroponics
7	A01G7	Botany
8	A01G9	Cultivation in receptacles, forcing-frames or greenhouses
9	B32B27	Layered products comprising synthetic resin
10	C08J5	Manufacture of articles or shaped materials containing macromolecular substances
11	E04B1	Constructions in general; Structures which are not restricted either to walls, e.g. partitions, or floors or ceilings or roofs
12	E04D13	Special arrangements or devices in connection with roof coverings; Roof drainage
13	G06Q50	Systems or methods specially adapted for specific business sectors
14	Y02A20	Water conservation; Efficient water supply; Efficient water use
15	Y02B10	Integration of renewable energy sources in buildings
16	Y02E10	Energy generation through renewable energy sources
17	Y02P60	Technologies relating to agriculture, livestock or agroalimentary industries

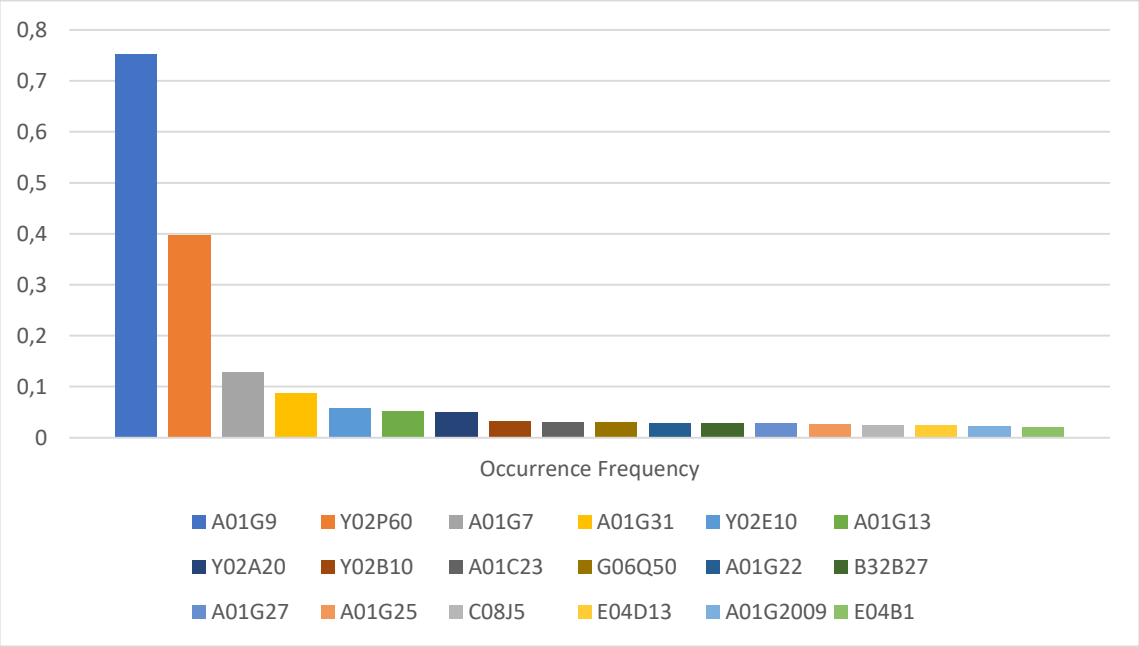


Figure 4.3 Comparison of the frequency of occurrence of CPC codes

Regarding the selection of technology, at first glance, "A01G9", "Y02P60", "A01G7", each of which appears in at least 10% of the patents While CPC codes can be considered to provide the answer, the selection of technology is not only a frequency-based indicator. Considering the fusion effect created and to be created by the use of more than one technological field, the importance of examining technology fields together is perceived instead of considering technological fields alone. In this context, the FP-Growth Algorithm, which can evaluate the presence and association relations of the values determined in the dataset in multiple groups, also provides researchers with information about the technologies used together in the patent dataset. The result table of the FP-Growth Algorithm for identifying pair values with a support value higher than 0.02 is presented in Table 4.4

Table 4.4 Result table of FP-Growth Algorithm on CPC code doubles

Antecedents	Consequents	Antecedent support	Consequent support	Support	Confidence	Lift	Leverage	Conviction
A01G9	Y02P60	0,7514	0,3975	0,2031	0,2703	0,6800	-0,0956	0,8257
Y02P60	A01G9	0,3975	0,7514	0,2031	0,5109	0,6800	-0,0956	0,5084
A01G7	A01G9	0,1287	0,7514	0,1244	0,9664	1,2863	0,0277	7,4112
A01G9	A01G7	0,7514	0,1287	0,1244	0,1655	1,2863	0,0277	1,0441
A01G31	A01G9	0,0878	0,7514	0,0834	0,9501	1,2645	0,0174	4,9803
A01G9	A01G31	0,7514	0,0878	0,0834	0,1110	1,2645	0,0174	1,0261
A01G31	Y02P60	0,0878	0,3975	0,0797	0,9082	2,2849	0,0448	6,5650
Y02P60	A01G31	0,3975	0,0878	0,0797	0,2005	2,2849	0,0448	1,1410
A01G7	Y02P60	0,1287	0,3975	0,0659	0,5123	1,2888	0,0148	1,2353
Y02P60	A01G7	0,3975	0,1287	0,0659	0,1658	1,2888	0,0148	1,0445
Y02E10	Y02P60	0,0583	0,3975	0,0502	0,8597	2,1630	0,0270	4,2959
Y02P60	Y02E10	0,3975	0,0583	0,0502	0,1262	2,1630	0,0270	1,0777
A01G13	A01G9	0,0521	0,7514	0,0500	0,9592	1,2766	0,0108	6,0956
A01G9	A01G13	0,7514	0,0521	0,0500	0,0665	1,2766	0,0108	1,0154
A01G31	A01G7	0,0878	0,1287	0,0355	0,4042	3,1412	0,0242	1,4624
A01G7	A01G31	0,1287	0,0878	0,0355	0,2757	3,1412	0,0242	1,2594
A01G9	Y02E10	0,7514	0,0583	0,0338	0,0449	0,7702	-0,0101	0,9860
Y02E10	A01G9	0,0583	0,7514	0,0338	0,5787	0,7702	-0,0101	0,5902

Antecedents	Consequents	Antecedent support	Consequent support	Support	Confidence	Lift	Leverage	Conviction
A01C23	A01G9	0,0297	0,7514	0,0292	0,9826	1,3078	0,0069	14,3127
A01G9	A01C23	0,7514	0,0297	0,0292	0,0388	1,3078	0,0069	1,0095
A01G9	G06Q50	0,7514	0,0293	0,0286	0,0381	1,3002	0,0066	1,0091
G06Q50	A01G9	0,0293	0,7514	0,0286	0,9769	1,3002	0,0066	10,7629
A01G9	B32B27	0,7514	0,0281	0,0276	0,0368	1,3096	0,0065	1,0090
B32B27	A01G9	0,0281	0,7514	0,0276	0,9839	1,3096	0,0065	15,4872
Y02B10	Y02P60	0,0322	0,3975	0,0273	0,8477	2,1326	0,0145	3,9560
Y02P60	Y02B10	0,3975	0,0322	0,0273	0,0686	2,1326	0,0145	1,0391
A01G22	A01G9	0,0286	0,7514	0,0270	0,9426	1,2545	0,0055	4,3294
A01G27	A01G9	0,0277	0,7514	0,0270	0,9721	1,2938	0,0061	8,9202
A01G9	A01G22	0,7514	0,0286	0,0270	0,0359	1,2545	0,0055	1,0076
A01G9	A01G27	0,7514	0,0277	0,0270	0,0359	1,2938	0,0061	1,0085
Y02B10	Y02E10	0,0322	0,0583	0,0256	0,7976	13,6705	0,0238	4,6523
Y02E10	Y02B10	0,0583	0,0322	0,0256	0,4395	13,6705	0,0238	1,7269
A01G25	A01G9	0,0261	0,7514	0,0240	0,9185	1,2225	0,0044	3,0516
A01G9	A01G25	0,7514	0,0261	0,0240	0,0319	1,2225	0,0044	1,0060
A01G9	E04D13	0,7514	0,0233	0,0229	0,0305	1,3107	0,0054	1,0075
E04D13	A01G9	0,0233	0,7514	0,0229	0,9848	1,3107	0,0054	16,3429
A01G9	C08J5	0,7514	0,0235	0,0226	0,0300	1,2762	0,0049	1,0067
C08J5	A01G9	0,0235	0,7514	0,0226	0,9589	1,2762	0,0049	6,0504

Table 4.4 provides information on the frequency of occurrence of CPC code pairs, as well as the confidence value of the occurrence of the other pair in patents in which one CPC code appears, or the strength of the relationship between the two codes, or the rates of co-occurrence and separate occurrence of the respective CPC codes.

In this thesis, only the combined use of two technologies is set as a target criterion for the examined technology selection issue. For this reason, Table 44 and the FP-Growth table have been simplified to show only the support value of the CPC code twos, i.e. the frequency of co-occurrence, and the table is ready to be used in the next stage of the Multi-criteria decision making methods.

Table 4.5 Frequency of co-occurrence of CPC code doubles

Rank	CPC Codes	Frequency of co-occurrence
1	A01G9:Y02P60	0,2031
2	A01G9:A01G7	0,1244
3	A01G9:A01G31	0,0834
4	Y02P60:A01G31	0,0797
5	Y02P60:A01G7	0,0659
6	Y02P60:Y02E10	0,0502
7	A01G9:A01G13	0,0500
8	A01G7:A01G31	0,0355
9	A01G9:Y02E10	0,0338
10	A01G9:A01C23	0,0292
11	A01G9:G06Q50	0,0286
12	A01G9:B32B27	0,0276
13	Y02P60:Y02B10	0,0273
14	A01G9:A01G22	0,0270
15	A01G22:A01G9	0,0270
16	Y02E10:Y02B10	0,0256
17	A01G9:A01G25	0,0240
18	A01G9:E04D13	0,0229
19	A01G9:C08J5	0,0226

4.3. MULTI-CRITERIA DECISION MAKING

4.3.1. DEFINING CRITERIA

Beyond the search for relationality and association within patent data, the importance of a technology in a field cannot be determined by its frequent use alone. This and similar predictive information will only support the pursuit of what already exists. However, the selection of innovative technologies is a multi-criteria decision-making problem that goes beyond frequency of availability. Therefore, to perform technology selection, we first need to categorize and identify valuable information in patent data according to criteria.

Within the scope of this thesis, 5 criteria were defined by considering the valuable data in the patent data in the creation of the decision table.

1- Support value: The frequency of CPC pairs in the total data set.

This criterion will be determined according to the values obtained with the FP-Growth algorithm and the data presented in TABLE 55 will be taken.

2- Average Patent age: The importance of innovation in technology studies should be taken into consideration. In this context, the average age values of patents with a CPC code pair will also provide important information about the novelty and currency of those patent applications.

In order to calculate the values under this criterion, the ages of the patents with the relevant CPC code pair will be summed, divided by the total number of occurrences and averaged.

3 and 4 - Average back citation value and Average forward citation value : As in all technical studies, citation stands out as an element that supports the value of a patent and the importance of its technology and is considered as one of the important values when calculating the importance of a patent. In this context, accepting citation values as a criterion may be a supportive element for the accuracy of the analysis.

In order to calculate the values within the scope of these criteria, the forward and backward citation values in patents with the relevant CPC code pair will be summed separately, divided by the total number of occurrences and averaged.

5- The average number of patents of patent leaders in a given field, or simply average firm strength. This value, which can be seen as an innovative criterion value, is based on the principle that the competence and strength of the applicant company is extremely important in determining the value of a patent.

In order to calculate the values within the scope of this criterion, firstly, the total number of patents that each patent applicant in the patent data set

I identified in the field of Greenhouse Technology has in the specified range was determined by means of a software code phrase.

These patent numbers were used as a numerical indicator for the relevant applicants. (Gocen, 2022) Then, the total number of patent applications in the relevant field for the applicants with the relevant CPC code pair, as seen in Table 4.6, will be summed up, divided by the total number of occurrences and averaged. With this method, it is aimed to take into account the power of the applicant company in the field within the analysis.

Table 4.6 List of applicants with the highest number of patents among patents received in the research data sample (Top 20 entries)

No	Institution Name[1]	Number of Patents[2]
1	GROW SOLUTIONS TECH LLC	455
2	EASTMAN CHEM CO	179
3	OCADO INNOVATION LTD	99
4	HAYGROVE LTD	76
5	UNIV CHINA AGRICULTURAL	75
6	REPUBLIC KOREA MAN RURAL DEV	69
7	ASAHI GLASS CO LTD	67
8	UNIV SHENYANG AGRICULTURAL	64
9	SVENSSON LUDVIG AB	62
10	LG ELECTRONICS INC	55
11	PANASONIC IP MAN CO LTD	50
12	REPUBLIC KOREA MAN RURAL DEV ADMIN	49
13	GREEN PLUS CO LTD	49
14	UNIV NORTHWEST A&F	46
15	DOW AGROSCIENCES LLC	46
16	대한민국	45
17	TOTO KOGYO KK	44
18	SHENZHEN QIANHAI HONGJIA TECH CO LTD	44
19	UNIV SHANDONG AGRICULTURAL	43

[1] The names of the organizations are written exactly as stated in the patent documents.
[2] The number of patents value represents the number of patents with the CPC code "Y02A40/25" (which represents "GREENHOUSE TECHNOLOGIES") of the listed companies.

No	Institution Name[1]	Number of Patents[2]
20	SEIWA CO LTD	42

The values were calculated as specified in the definitions of the criteria and put together in the form of a decision table, which can be seen in Table 4.7.

Table 4.7 The basic decision table, after determining the criteria

Raw Decision Table	Frequency of Occurrence	Average Patent Age	Average Power of Company	Average Number of Patents Cited	Average Number of Patents Cited by
A01G9:Y02P60	0,2031	4,8652	38,7498	4,8087	0,3544
A01G9:A01G7	0,1244	3,9699	37,1974	4,7632	0,3896
A01G9:A01G31	0,0834	4,1878	87,9494	5,0193	0,4097
Y02P60:A01G31	0,0797	4,1722	87,7726	4,9903	0,4155
Y02P60:A01G7	0,0659	4,1452	65,1972	5,0582	0,4481
Y02P60:Y02E10	0,0502	5,3513	6,0057	3,5055	0,3047
A01G9:A01G13	0,0500	5,4884	13,4070	4,0670	0,2218
A01G7:A01G31	0,0355	3,7866	114,4184	4,6948	0,4360
A01G9:Y02E10	0,0338	5,6918	6,7526	5,3950	0,3542
A01G9:A01C23	0,0292	2,9249	15,6075	3,6773	0,3396
A01G9:G06Q50	0,0286	2,8953	135,0447	2,5383	0,2908
A01G9:B32B27	0,0276	8,0303	45,5698	14,1131	0,2520
Y02P60:Y02B10	0,0273	5,9243	5,8680	3,5626	0,3365
A01G9:A01G22	0,0270	3,8029	12,2338	4,1768	0,3429
A01G22:A01G9	0,0270	3,8029	12,2338	4,1768	0,3429
Y02E10:Y02B10	0,0256	5,9749	5,8727	3,7374	0,3345
A01G9:A01G25	0,0240	4,5121	59,9765	4,3011	0,3202
A01G9:E04D13	0,0229	8,1433	48,4002	16,6854	0,3246
A01G9:C08J5	0,0226	8,2057	51,1258	16,4129	0,2531

4.3.2. ENTROPY WEIGHT AND TOPSIS METHOD

The steps for applying the Entropy method described in the Methods section were followed.

1- Normalizing the decision matrix to ignore irregularities with different evaluation entities and ratios is the original decision matrix, as seen in Table 4.8

Table 4.8 Entropy Normalized Decision Matrix

Entropy Normalized Decision Matrix	Frequency of Occurrence	Average Patent Age	Average Power of Company	Average Number of Patents Cited	Average Number of Patents Cited by
A01G9:Y02P60	0,2013	0,0486	0,0448	0,0404	0,0528
A01G9:A01G7	0,1232	0,0397	0,0430	0,0400	0,0580
A01G9:A01G31	0,0826	0,0419	0,1016	0,0421	0,0610
Y02P60:A01G31	0,0790	0,0417	0,1014	0,0419	0,0618
Y02P60:A01G7	0,0653	0,0414	0,0753	0,0425	0,0667
Y02P60:Y02E10	0,0497	0,0535	0,0069	0,0294	0,0454
A01G9:A01G13	0,0495	0,0549	0,0155	0,0341	0,0330
A01G7:A01G31	0,0351	0,0378	0,1322	0,0394	0,0649
A01G9:Y02E10	0,0335	0,0569	0,0078	0,0453	0,0527
A01G9:A01C23	0,0289	0,0292	0,0180	0,0309	0,0506
A01G9:G06Q50	0,0283	0,0289	0,1560	0,0213	0,0433
A01G9:B32B27	0,0274	0,0803	0,0526	0,1184	0,0375
Y02P60:Y02B10	0,0270	0,0592	0,0068	0,0299	0,0501
A01G9:A01G22	0,0267	0,0380	0,0141	0,0351	0,0510
A01G22:A01G9	0,0267	0,0380	0,0141	0,0351	0,0510
Y02E10:Y02B10	0,0254	0,0597	0,0068	0,0314	0,0498
A01G9:A01G25	0,0238	0,0451	0,0693	0,0361	0,0477
A01G9:E04D13	0,0227	0,0814	0,0559	0,1400	0,0483
A01G9:C08J5	0,0223	0,0820	0,0591	0,1377	0,0377

Then entropy, deviation and weight values were calculated for each criterion and recorded in Table 4.9

Table 4.9 Entropy weight result table

	Frequency of Occurrence	Average Patent Age	Average Power of Company	Average Number of Patents Cited	Average Number of Patents Cited by
Entrophy	0,90906	0,98449	0,87835	0,93697	0,99428
Deviation value	0,09094	0,01551	0,12165	0,06303	0,00572
Weight Value	0,30636	0,05223	0,40982	0,21232	0,01926

After determining the weight values with the entropy method, TOPSIS was applied. Within the TOPSIS study, first the normalized decision matrix was prepared as in Table 4.10, and then the weighted normalized decision matrix was

obtained as in Table 4.11 by using the weighting values in Table 4.9 we obtained in the previous study.

Table 4.10 TOPSIS Normalized Matrix

TOPSIS Normalized Matrix	Frequency of Occurrence	Average Patent Age	Average Power of Company	Average Number of Patents Cited	Average Number of Patents Cited by
A01G9:Y02P60	0,6802	0,2075	0,1512	0,1477	0,2320
A01G9:A01G7	0,4165	0,1693	0,1451	0,1463	0,2551
A01G9:A01G31	0,2793	0,1786	0,3432	0,1541	0,2682
Y02P60:A01G31	0,2670	0,1779	0,3425	0,1532	0,2720
Y02P60:A01G7	0,2208	0,1768	0,2544	0,1553	0,2934
Y02P60:Y02E10	0,1680	0,2282	0,0234	0,1076	0,1995
A01G9:A01G13	0,1675	0,2341	0,0523	0,1249	0,1452
A01G7:A01G31	0,1188	0,1615	0,4465	0,1442	0,2855
A01G9:Y02E10	0,1131	0,2428	0,0263	0,1657	0,2319
A01G9:A01C23	0,0977	0,1247	0,0609	0,1129	0,2224
A01G9:G06Q50	0,0958	0,1235	0,5270	0,0779	0,1904
A01G9:B32B27	0,0926	0,3425	0,1778	0,4334	0,1650
Y02P60:Y02B10	0,0913	0,2527	0,0229	0,1094	0,2203
A01G9:A01G22	0,0903	0,1622	0,0477	0,1283	0,2245
A01G22:A01G9	0,0903	0,1622	0,0477	0,1283	0,2245
Y02E10:Y02B10	0,0859	0,2548	0,0229	0,1148	0,2190
A01G9:A01G25	0,0803	0,1924	0,2340	0,1321	0,2097
A01G9:E04D13	0,0768	0,3473	0,1889	0,5124	0,2125
A01G9:C08J5	0,0755	0,3500	0,1995	0,5040	0,1657

Table 4.11 Entropy Weighted Normalized Matrix

Entropy Weighted Normalized Matrix	Frequency of Occurrence	Average Patent Age	Average Power of Company	Average Number of Patents Cited	Average Number of Patents Cited by
A01G9:Y02P60	0,2084	0,0108	0,0620	0,0314	0,0045
A01G9:A01G7	0,1276	0,0088	0,0595	0,0311	0,0049
A01G9:A01G31	0,0856	0,0093	0,1406	0,0327	0,0052
Y02P60:A01G31	0,0818	0,0093	0,1404	0,0325	0,0052
Y02P60:A01G7	0,0676	0,0092	0,1043	0,0330	0,0057
Y02P60:Y02E10	0,0515	0,0119	0,0096	0,0229	0,0038
A01G9:A01G13	0,0513	0,0122	0,0214	0,0265	0,0028
A01G7:A01G31	0,0364	0,0084	0,1830	0,0306	0,0055
A01G9:Y02E10	0,0346	0,0127	0,0108	0,0352	0,0045
A01G9:A01C23	0,0299	0,0065	0,0250	0,0240	0,0043

Entropy Weighted Normalized Matrix	Frequency of Occurrence	Average Patent Age	Average Power of Company	Average Number of Patents Cited	Average Number of Patents Cited by
A01G9:G06Q50	0,0294	0,0065	0,2160	0,0165	0,0037
A01G9:B32B27	0,0284	0,0179	0,0729	0,0920	0,0032
Y02P60:Y02B10	0,0280	0,0132	0,0094	0,0232	0,0042
A01G9:A01G22	0,0277	0,0085	0,0196	0,0272	0,0043
A01G22:A01G9	0,0277	0,0085	0,0196	0,0272	0,0043
Y02E10:Y02B10	0,0263	0,0133	0,0094	0,0244	0,0042
A01G9:A01G25	0,0246	0,0101	0,0959	0,0280	0,0040
A01G9:E04D13	0,0235	0,0181	0,0774	0,1088	0,0041
A01G9:C08J5	0,0231	0,0183	0,0818	0,1070	0,0032
A01G9:A01G2009	0,2084	0,0108	0,0620	0,0314	0,0045

Based on the data in this normalized weighted decision matrix, the best and worst options for each criterion were determined in Table 4.12, and separation measures were calculated as in Table 4.13 for each criterion with the help of the values.

Table 4.12 Positive and negative ideal solutions

Positive and negative ideal solutions	Frequency of Occurrence	Average Patent Age	Average Power of Company	Average Number of Patents Cited	Average Number of Patents Cited by
V+	0,2084	0,0065	0,2160	0,1088	0,0057
V-	0,0221	0,0183	0,0094	0,0165	0,0028

Table 4.13 Seperation Values for Options

Seperation Values	Si+	Si-
A01G9:Y02P60	0,172424	0,194248
A01G9:A01G7	0,192511	0,118048
A01G9:A01G31	0,162964	0,146960
Y02P60:A01G31	0,166038	0,145101
Y02P60:A01G7	0,195053	0,106915
Y02P60:Y02E10	0,273178	0,030679
A01G9:A01G13	0,263299	0,033638
A01G7:A01G31	0,191805	0,175038
A01G9:Y02E10	0,278820	0,023222
A01G9:A01C23	0,274831	0,022332
A01G9:G06Q50	0,201418	0,207040

Seperation Values	Si+	Si-
A01G9:B32B27	0,230879	0,098819
Y02P60:Y02B10	0,287398	0,010314
A01G9:A01G22	0,279091	0,018622
A01G22:A01G9	0,279091	0,018622
Y02E10:Y02B10	0,288100	0,010257
A01G9:A01G25	0,233947	0,087718
A01G9:E04D13	0,231327	0,114620
A01G9:C08J5	0,229086	0,115856

In the final stage of TOPSIS, the ideal solution values were calculated and the preference options were ranked in according to this value in Table 4.14.

Table 4.14 Ranking of Alternatives as a Result of Scenario Analysis

Selection Rank According to TOPSIS	CPC Group Codes	Ideal Solution Value
1	A01G9:Y02P60	0,52976
2	A01G9:G06Q50	0,50688
3	A01G7:A01G31	0,47715
4	A01G9:A01G31	0,47418
5	Y02P60:A01G31	0,46635
6	A01G9:A01G7	0,38011
7	Y02P60:A01G7	0,35406
8	A01G9:C08J5	0,33587
9	A01G9:E04D13	0,33132
10	A01G9:B32B27	0,29973
11	A01G9:A01G25	0,27270
12	A01G9:A01G13	0,11328
13	Y02P60:Y02E10	0,10096
14	A01G9:Y02E10	0,07688
15	A01G9:A01C23	0,07515
16	A01G9:A01G22	0,06255
17	A01G22:A01G9	0,06255
18	Y02P60:Y02B10	0,03465
19	Y02E10:Y02B10	0,03438

When the ranked Table 4.14 prepared after the decision analysis according to the TOPSIS Method is examined, it can be noticed that the ranking after FP-Growth

is significantly different from the ranking after FP-Growth. The CPC code pair "A01G9- Cultivation in receptacles, forcing-frames or greenhouses" and "G06Q50-Systems or methods specially adapted for specific business sectors", which was previously ranked 11th, stands out as the most ideal solution as revealed by TOPSIS. However, the other 3 solutions listed in Table 4.15 with an ideal solution value above 0.45 are also close to the ideal solution.

Table 4.15 Ideal Solutions with value bigger than 0,45

No	CPC Group Codes	CPC Definations	Ideal Solution Value
1	Y02P60	Technologies relating to agriculture, livestock or agroalimentary industries	0,52976
	A01G9	Cultivation in receptacles, forcing-frames or greenhouses	
2	A01G9	Cultivation in receptacles, forcing-frames or greenhouses	0,50688
	G06Q50	Systems or methods specially adapted for specific business sectors	
3	A01G7	Botany, treatment of plants	0,47715
	A01G31	Soilless cultivation, e.g. Hydroponics	
4	A01G9	Cultivation in receptacles, forcing-frames or greenhouses	0,47418
	A01G31	Soilless cultivation, e.g. Hydroponics	
5	Y02P60	Technologies relating to agriculture, livestock or agroalimentary industries	0,46635
	A01G31	Soilless cultivation, e.g. Hydroponics	

When these solutions are analyzed, it becomes clear that Greenhouse technology has developed alongside the technology areas of Cultivation (A01G9), Botany and processing of plants (A01G7), Hydroponics (A01G31), Agriculture-related technologies (Y02P60) and, perhaps most importantly, systems or methods tailored for specific business sectors (G06Q50). The term systems or methods is used to describe information systems and related algorithms according to the patent methodology. Agriculture-related technologies also refer to developments in electronic and information system infrastructures in agriculture.

Furthermore, focusing on the code Y02P60, given that the most frequent sub-group in this CPC code group in the data set within the thesis is Y02P60/14 Measures for saving energy (in greenhouses), it will be determined that the

innovation work done and to be done in the greenhouse field is focused on energy efficiency in greenhouses.

In other words, the CPC code G06Q50, which ranks 10th in the ranking of unique CPC occurrence frequency and appears in less than 3% of existing patents, indicates that leading companies in Greenhouse technology are largely focused on software used in Greenhouse technologies, given that the company strength criterion gains a high weight value on the results of the entropy weighting method.

5. DISCUSSION AND CONCLUSION

Selecting the right technology is one of the most important criteria for the progress and even sustainability of companies engaged in R&D today. In order to make the right choice, it is necessary to act with as much new and reliable information as possible on competitors and markets. If the choice of technology is based solely on market data, it is too late in the technology life cycle of an innovation, which is important for bringing many innovative products to the market, and the expected high input from the studies is not achieved.

In contrast, patents provide the clearest and most up-to-date information on products that have not yet reached the market and on competitors that are doing R&D. In this context, with the aim of bringing a breath of fresh air and an option to the problem of technology selection, this thesis was initiated with the research statement "Which technology should companies conducting innovation studies in a technology field choose to develop and strengthen in addition to their main technology areas in order to advance in their fields and to obtain innovative outputs, and can patent data and patent analysis be used for this choice?".

In this context, when the studies in the literature are examined, it is seen that the most appropriate option is the use of Multi-Criteria Decision Making methods that compare patent data in many aspects. Since the nature of our research question is a multi-criteria selection problem, methods for solving the selection problem among Multi-Criteria Decision Making methods were examined and TOPSIS method was selected to be applied to the problem, again based on the literature data.

Since similar studies and applications have not yet been applied in practice in the field of Technology selection with the data obtained from the Patents determined in the studies carried out for criteria weighting, which is needed to apply TOPSIS, and especially in the Greenhouse Technologies sector, which is applied as an example, an objective weighting system was examined for this innovative idea. When the literature studies were examined, it was seen that by using objective weighting methods, the application could be developed using the TOPSIS method with Entropy weighting.

The literature was examined to determine the criteria, and the criteria were determined from similar studies since there was no direct similar application. In this context, for the analysis study to be carried out in the determined technology, date range and CPC code;

1- Average frequency of occurrence

2- Average Patent Age

3- Average number of Forward citations

4- Average number of Back citations

5- Average number of patents obtained by leading companies in the technological field

criteria were determined and decision matrices were constructed according to these criteria.

Among these criteria, the average number of patents obtained by leading companies in the technological field is a very innovative criterion suggestion, and it is basically determined with the knowledge that in patent valuation, the organization that applied for that patent is a very important value. This innovative criterion, by taking the largest share in the criteria weighting, also stood out as the criterion that guided the analysis the most in finding the ideal solution.

Within the scope of the study, the development of a software program that will provide a suitable interface to the system in order to obtain patent data through the Open Patent System, which is granted access to researchers by the European Patent Office, was developed within the scope of another study of the researcher, and with this thesis, FP-Growth data mining algorithm, Entropy Weighting calculation and TOPSIS calculation methods were added to this software. With this software developed in Python language, Patent data was obtained as raw data and classified on the database. The use of this software provided access to bulk patent data that would not normally be accessible for free or by using web-based search engines. In this way, it was possible to make calculations about the criteria and to create a decision matrix. Within this data set, connectivity algorithms from data mining algorithms were evaluated and it was decided to apply the FP-Growth algorithm in consideration of the literature studies due to its speed and accuracy.

Within the scope of this algorithm, it was possible to obtain prioritized and frequent single CPC group codes and paired group codes from the analyzed data set.

Thanks to these studies, an answer to our research question was obtained. As a result, when the ideal result table is analyzed, it can be concluded that companies that carry out innovation studies on Greenhouse Technology should first focus on the development of software and algorithms that can be used in the Greenhouse and the development of cultivation techniques in the greenhouse in addition to the main technology areas in order to progress in their fields and to obtain innovative outputs. In this context, it is understood that software and operating algorithms that will support or enable the implementation of new cultivation techniques will be important for the development of Greenhouse technology innovation. In addition, the development of plant protection methods in soilless agriculture, the development of new cultivation techniques in soilless agriculture, and the development of electronic and software infrastructures in hydroponic systems in soilless agriculture are also important.

As a result, this study offers an innovative solution option for the effective use of patent data, which is an important data source in technology selection problems. As a result of this study, companies carrying out innovation studies in a technology field can benefit by using TOPSIS method with entropy weighting by utilizing patent data and analysis in their studies to choose which technology to develop and strengthen in addition to their main technology areas in order to progress in their fields and to obtain innovative outputs.

However, to ensure that the research provides more accurate and consistent methods, in future studies;

1- CPC code-based studies can be greatly improved with the results obtained from semantic data analysis methods that can support automatic classification with artificial intelligence on patent data, since the process of adding CPC codes has not yet been completed in patents with new application dates.

2- By developing new criteria within the decision matrix, the study can be improved by adding information such as the patent ratios of the applicant

companies in and out of the field and patent family information to the criteria and by proposing methods to objectively calculate these criteria.

3- By examining the frequency of CPC codes with a time series analysis, it will be possible to evaluate the usage habits of the identified CPC codes and the solutions they will reveal in terms of life cycle analysis.

4- Following the increase of studies and observations in the field, ideal solutions can be developed with the support of experts by consulting the knowledge of experts in weighting.

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CURRICULUM VITAE

PERSONAL INFORMATION

Name: M****t U**r

Surname: G***N

Date of Birth: 2*/0*/1**4

Mobil Phone: +90 5********6

Email: u****n@g***l.c*m

EDUCATIONAL BACKGROUND

2**4 - Bachelor of Arts Degree in Business Administration, Anadolu University

2**1 - Bachelor of Arts Degree in Management Information Systems, Anadolu University

APPENDICES

Page

APPENDIX A: Table of Acquired Patent Data Sample (First 100 entries)

No	Publication Date	Application Number	Title	Applicants[1]	Cites Patent Count	Cited by Patent Count	CPC Classifications
1	31.12.2021	CN 202121783247 U	Vegetable greenhouse capable of conveniently adjusting temperature and humidity	ZHAO JUNMEI	0	0	Y02A20/108, Y02A40/25
2	31.12.2021	CN 202121520970 U	Water and fertilizer integrated micro-spraying drip irrigation assembly for agricultural greenhouse	TIANJIN AGRICULTURE DEV SERVICE CENTER	0	0	Y02A40/25
3	31.12.2021	CN 202120430688 U	Heating equipment for greenhouse seedling raising	SHANDONG LUSHOU SEED IND CO LTD	0	0	Y02A40/25
4	31.12.2021	CN 202120560214 U	Forestry engineering seedling cultivation device	ZHENG MINGLING	0	0	Y02A20/108, Y02A40/25, Y02P60/14
5	31.12.2021	CN 202010690408 A	Original ecological glass curtain wall plastic greenhouse	FUZHOU HUAXIA ROOF AGRICULTURAL TECH DEVELOPMENT CO LTD	0	0	A01G9/14, A01G9/246, A01G13/00, Y02A40/25
6	31.12.2021	CN 202121426209 U	Lily bulb cultivation device	GUANGXI ACADEMY AGRICULTURAL SCIENCES	0	0	Y02A40/25
7	31.12.2021	CN 202111319672 A	Intelligent adjusting greenhouse structure	CHENG MEI	0	0	A01G9/14, A01G9/22, A01G9/243, A01G9/26, E03B3/02, Y02A20/108, Y02A40/25, Y02P60/12, Y02P60/14
8	31.12.2021	CN 202121495370 U	Intelligent room temperature control device for greenhouse	HENAN YUTUO AGRICULTURAL TECH CO LTD	0	0	Y02A40/25
9	31.12.2021	CN 202120598953 U	Bletilla striata planting shed	YUNNAN XUEAN AGRICULTURAL TECH CO LTD	0	0	Y02A20/108, Y02A40/25

[1] The names of the organizations are written exactly as stated in the patent documents.

No	Publication Date	Application Number	Title	Applicants[1]	Cites Patent Count	Cited by Patent Count	CPC Classifications
10	31.12.2021	CN 202111267731 A	Sprinkling irrigation equipment for greenhouse fruit and vegetable planting	JIANGSU TIANSHUI IRRIGATION AND DRAINAGE EQUIPMENT CO LTD	0	0	A01G9/247, Y02A40/25
11	31.12.2021	CN 202023327316 U	Illumination incubator for Chinese herbal medicine seedling and breeding	CHANGZHOU MENGHE SHUANGFENG CHINESE HERBAL MEDICINE TECH CO LTD	0	0	Y02A40/25
12	31.12.2021	CN 202120350789 U	Blueberry planting spraying equipment capable of uniformly spraying	NANXIONG DINGFENG AGRICULTURAL TECH DEVELOPMENT CO LTD	0	0	Y02A40/25
13	31.12.2021	CN 202121222501 U	Spraying and irrigating system for growing seedlings of local capsicum annuum	GANSU LONGSHANGJIAO AGRICULTURAL TECH GROUP CO LTD	0	0	Y02A40/25
14	31.12.2021	CN 202111288314 A	Method and device for radish seed production by utilizing osmia	JIANGSU LITTORAL AGRICULTURE SCIENCE RES INSTITUTE	8	0	A01G22/25, A01G9/14, A01G9/227, A01H1/021, Y02A40/25
15	31.12.2021	CN 202111227837 A	Multifunctional sprinkling irrigation equipment	JIANGSU MINGQUAN IRRIGATION AND DRAINAGE EQUIPMENT CO LTD	0	0	A01G9/247, A01G9/245, A01G9/246, A01G9/24, A01C23/042, A01M7/0042, Y02A40/25
16	31.12.2021	CN 202121751323 U	Seedling raising shed additionally provided with spraying equipment	DU PING	0	0	Y02A40/25
17	31.12.2021	CN 202080037949 A	GROWING SYSTEMS AND METHODS	OCADO INNOVATION LTD	0	0	A01G9/14, A01G9/0295, A01G7/045, A01G9/24, C12G1/0203, A01G31/06, A01G9/24, A01G17/00, A01G9/143, Y02A40/25, Y02P60/21, A01G9/24, A01G17/02, A01G31/06, A01G9/24, A01G9/143, A01G17/00,

No	Publication Date	Application Number	Title	Applicants[1]	Cites Patent Count	Cited by Patent Count	CPC Classifications
							A01G31/06, Y02A40/25, Y02P60/21, A01G9/143, A01G9/24, A01G17/00, A01G31/06
18	31.12.2021	CN 202111125018 A	Agricultural greenhouse joint protection system	JINGZHOU YANGXIAHONG MODERN AGRICULTURE CO LTD	0	0	A01G9/14, A01G9/24, A01G9/243, A01G9/249, A01G9/26, E04D13/106, E04D13/04, E04D13/00, E03B3/02, Y02A20/108, Y02A40/25, Y02B10/10, Y02P60/12
19	31.12.2021	MA 46015 A	Systèmes et procédés d'omission de récolte pour un module de culture	GROW SOLUTIONS TECH LLC	0	0	A01G9/088, A01G9/143, A01G31/042, G01N33/025, Y02A40/25, Y02P60/21, A01G7/045, A01G9/24, A01G7/00, A01G31/045, A01G9/143, B61B13/00, G05B19/042, G05D1/0027, G05B19/4189, G06Q50/02, A01G9/088, A01D91/00, A01G7/045, A01G9/143, A01G31/042, G01N33/025
20	31.12.2021	CN 202121617499 U	Building type greenhouse for agricultural technology planting industry	MA TAO	0	0	Y02A40/25
21	31.12.2021	CN 202121341191 U	Greenhouse plant disease control device	SUN XIUHUI	0	0	Y02A40/25
22	31.12.2021	CN 202121865979 U	Experimental device for researching interaction relationship between insects and living plants	UNIV GUIZHOU NORMAL	0	0	Y02A40/25

No	Publication Date	Application Number	Title	Applicants[1]	Cites Patent Count	Cited by Patent Count	CPC Classifications
23	31.12.2021	CN 202121850015 U	Garden seedling raising device	HUIZHOU KAISEN FOREST INDUSTRY TECH CO LTD	0	0	Y02A40/25
24	31.12.2021	CN 202023117787 U	Greenhouse sprayer	WUHU LECHUANG AGRICULTURAL FACILITIES CO LTD	0	0	Y02A40/25
25	31.12.2021	CN 202120589309 U	Height-adjustable spraying elevated seedbed	GUYUAN TIANQI POTATO IND CO LTD	0	0	Y02A40/25
26	31.12.2021	CN 202121628698 U	Greenhouse film pressing clamp	JIAXING LIANGQIAO AGRICULTURAL FACILITIES CO LTD	0	0	Y02A40/25
27	31.12.2021	CN 202121668755 U	Incubator for gastrodia elata planting	KANGXIAN JUKANGYUAN PLANTING FARMERS PROFESSIONAL COOP	0	0	Y02A40/25
28	31.12.2021	MA 45955 A	Systèmes pour fournir une capsule de culture de ligne d'assemblage	GROW SOLUTIONS TECH LLC	0	0	B65G43/02, B65G2207/24, A01G7/00, A01G9/18, A01G9/24, A01G31/042, B65G47/5113, Y02A40/25, Y02P60/21, A01G9/24, A01G31/042, A01G7/00, A01G25/16, B60L5/04, G06Q50/02, A01C7/00, G06Q10/06395, B65G2207/24, B65G43/02, A01G9/085, A01G9/24, A01G25/16, A01G31/042
29	31.12.2021	CN 202111321330 A	Culture device for lotus seed planting and use method thereof	FANCHANG COUNTY XIONGFENG FAMILY FARM	7	0	A01G9/16, A01G9/0293, A01G9/241, A01G9/246, A01G9/247, A01C23/047, Y02A40/25

No	Publication Date	Application Number	Title	Applicants[1]	Cites Patent Count	Cited by Patent Count	CPC Classifications
30	31.12.2021	CN 202121838289 U	Temperature regulation and control device used in agricultural greenhouse	JIANGXI WANFU IND GROUP CO LTD	0	0	Y02A40/25
31	31.12.2021	CN 202121294626 U	Dendrobium nobile planting greenhouse	ANHUI DABIESHAN DENDROBIUM HUOSHANENSE TECH CO LTD	0	0	Y02A40/25
32	31.12.2021	CN 202121778798 U	Wind-resistant agricultural greenhouse based on agricultural internet of things	GUANGZHOU SUICHENG NETWORK TECH CO LTD	0	0	Y02A40/25
33	31.12.2021	CN 202121014989 U	Multi-angle adjustable light supplementing device for greenhouse	SHANDONG LISENTE AGRICULTURAL TECH CO LTD	0	0	Y02A40/25
34	31.12.2021	CN 202111283759 A	Graphene radiation enhancement device for greenhouse	BEIJING LVNENG JIAYE NEW ENERGY CO LTD	0	0	H05B3/02, H05B3/20, A01G9/14, A01G9/24, Y02A40/25, Y02P60/12
35	31.12.2021	CN 202111319588 A	Fruit tree seedling cultivation equipment	LIANGSHAN COUNTY FORESTRY PROT AND DEVELOPMENT SERVICE CENTER	10	0	A01G9/029, A01G25/02, Y02P60/21, Y02A40/25
36	31.12.2021	CN 202010987965 A	Indoor cultivation equipment for polygonatum kingianum	HUNAN SHISHANGKANG AGRICULTURE CO LTD	5	0	A01G9/20, A01G9/249, A01G9/247, A01G7/045, A01C23/047, A01M7/0032, A01M7/0089, A01C23/007, Y02A40/25
37	31.12.2021	CN 202121896605 U	Seedling constant-temperature cultivation box	HANGZHOU LINAN YUQIAN PEOPLES GOVERNMENT, HANGZHOU LINAN AGRICULTURE AND FORESTRY TECH POPULARIZATION CENTER, UNIV ZHEJIANG A&F	0	0	Y02A40/25

No	Publication Date	Application Number	Title	Applicants[1]	Cites Patent Count	Cited by Patent Count	CPC Classifications
38	31.12.2021	CN 202120115217 U	Automatic organic fertilizer water spraying system based on Internet	YANTAI HONGYUAN BIOLOGICAL FERTILIZER CO LTD	0	0	Y02A40/25
39	31.12.2021	CN 202120884100 U	Seedling raising box for forestry	ZHANG CHENG	0	0	Y02A40/25
40	31.12.2021	CN 202121360217 U	Ejector head	DONGGUAN HUACHUANG CARBON FIBER TECH CO LTD	0	0	Y02A40/25
41	31.12.2021	CN 202121222510 U	Automatic pepper seedling raising greenhouse	GANSU LONGSHANGJIAO AGRICULTURAL TECH GROUP CO LTD	0	0	Y02A40/25
42	31.12.2021	CN 202111188549 A	Forestry breeding cultivation device capable of adjusting cultivation environment	QIU XIAOMEI	5	0	A01G31/06, A01G31/02, Y02P60/21, Y02A40/25
43	31.12.2021	CN 202121858022 U	Simple movable drought resisting shed device for peanuts	LIAONING SAND TREAT AND UTILIZATION INSTITUTE	0	0	Y02A40/25
44	31.12.2021	CN 202121805090 U	Thermotank for forestry seedling cultivation	HENAN RONGTENG FOREST PLANTING CO LTD	0	0	Y02A40/25
45	31.12.2021	CN 202111186857 A	Intelligent irrigation system for agricultural greenhouse	REN JINNA	10	0	A01G9/247, E04D13/106, Y02A40/25
46	31.12.2021	CN 202121800662 U	Forestry seedling raising device	ZHANG TIANTIAN	0	0	Y02A40/25
47	31.12.2021	CN 202121474174 U	Special cultivation box for seedling cultivation	NINGXIA HUIMINFENG AGRICULTURE AND FORESTRY DEV CO LTD	0	0	Y02A40/25
48	31.12.2021	CN 202120649460 U	Peony seedling growing environment control device	TONGLING WUTONGSHU AGRICULTURAL DEV CO LTD	0	0	Y02A40/25

No	Publication Date	Application Number	Title	Applicants[1]	Cites Patent Count	Cited by Patent Count	CPC Classifications
49	31.12.2021	CN 202111193049 A	Vertical column structure in multi-span greenhouse, using method and multi-span greenhouse	INST OF ENVIRONMENT AND SUSTAINABLE DEVELOPMENT IN AGRICULTURE CHINESE ACADEMY OF AGRICULTURAL SCIEN	0	0	A01G9/14, A01G9/24, Y02A40/25, Y02P60/14
50	31.12.2021	CN 202120435737 U	Limiting structure for seedling raising machine	SHANDONG LUSHOU SEED IND CO LTD	0	0	Y02A40/25
51	31.12.2021	CN 202121743153 U	Irrigation device for agricultural greenhouse	ANQING RUNJIA ECOLOGICAL AGRICULTURE TECH DEVELOPMENT CO LTD	0	0	Y02A40/25
52	31.12.2021	CN 202122111118 U	Temperature-adjustable agricultural planting box	LIU QINGYAN	0	0	Y02A40/25
53	31.12.2021	CN 202120636472 U	Novel seedling cultivation device	NONGXIN INTELLIGENT TECH SHANDONG CO LTD	0	0	Y02A40/25
54	31.12.2021	CN 202121115388 U	Integrated photovoltaic agricultural greenhouse convenient to maintain	JILIN AGRICULTURAL SCIENCE AND TECHNOLOGY UNIV	0	0	Y02A40/25, Y02P60/12
55	31.12.2021	CN 202120436367 U	Temperature control equipment for vegetable breeding	SHANDONG LUSHOU SEED IND CO LTD	0	0	Y02A40/25
56	31.12.2021	CN 202121010454 U	Seedling raising device for greenhouse vegetable planting	TONGREN AGRICULTURE AND ANIMAL HUSBANDRY COMPREHENSIVE SERVICE CENTER	0	0	Y02A40/25
57	31.12.2021	CN 202121347948 U	Full-automatic malt grass planting equipment	INNER MONGOLIA WISDOM XINGMU IOT TECH CO LTD	0	0	Y02A40/25
58	31.12.2021	CN 202121779525 U	Agricultural breeding culture device based on Internet of Things	GUANGZHOU SUICHENG NETWORK TECH CO LTD	0	0	Y02A40/25

No	Publication Date	Application Number	Title	Applicants[1]	Cites Patent Count	Cited by Patent Count	CPC Classifications
59	31.12.2021	CN 202111081633 A	Method for improving drought resistance and salt resistance of dianthus superbus	ZHEJIANG SUB TROPICS CROP INST, ZHEJIANG YUANYE CONSTRUCTION CO LTD, WENZHOU QINGYUAN GARDENING TECH CO LTD	6	0	A01G22/00, A01G22/60, A01G31/00, A01G7/06, A01G24/28, A01G24/15, A01G24/10, A01G24/22, A01N33/22, A01N37/40, Y02A40/25, Y02A40/10
60	31.12.2021	CN 202121110068 U	Intelligent agricultural greenhouse control device	LIAONING FANSHANG TECH CO LTD	0	0	Y02A40/25
61	31.12.2021	CN 202121837369 U	Spring pennisetum purpureum seed stem germination accelerating and seedling raising device	UNIV SICHUAN AGRICULTURAL, SICHUAN JIANGFUMAO AGRICULTURAL DEV CO LTD	0	0	Y02A40/25
62	31.12.2021	CN 202121564281 U	Cleaning device for greenhouse film	GANSU FUYU PLASTIC IND CO LTD	0	0	Y02A40/25
63	31.12.2021	CN 202121682842 U	Row type potted Chinese rose irrigation device	UNIV ANHUI AGRICULTURAL, ANHUI BAIHUI GARDEN CO LTD	0	0	Y02A40/25
64	31.12.2021	CN 201811536347 A	一种种植系统及方法	浙江国自机器人技术股份有限公司	0	0	A01G9/085, A01G9/14, A01G9/28, B65G59/067, B65G2201/0258, Y02A40/25
65	31.12.2021	CN 202121668425 U	Three-dimensional planting seedbed for gastrodia elata	KANGXIAN JUKANGYUAN PLANTING FARMERS PROFESSIONAL COOP	0	0	Y02A40/25
66	31.12.2021	CN 202023112705 U	Greenhouse drainage channel convenient for cleaning filtered objects	WUHU LECHUANG AGRICULTURAL FACILITIES CO LTD	0	0	Y02A20/108, Y02A40/25
67	31.12.2021	CN 202121595021 U	Hot air anti-freezing system device	ZHEJIANG LIANGSHAN BIOTECHNOLOGY CO LTD	0	0	Y02A40/25
68	31.12.2021	CN 202121554729 U	Irrigation system for grape orchard	CHANGXING LIJIAXIANG JINGJIN FAMILY FARM	0	0	Y02A40/25

No	Publication Date	Application Number	Title	Applicants[1]	Cites Patent Count	Cited by Patent Count	CPC Classifications
69	31.12.2021	CN 202121879469 U	Protection device for agricultural product seed cultivation	SUN XIAOJIN	0	0	Y02A40/25
70	31.12.2021	CN 202111309485 A	Vine seedling cutting seedling raising seedbed for municipal landscaping	LI HUI	0	0	A01G9/28, A01G9/029, A01G9/14, A01G9/247, A01G9/249, Y02A40/25
71	31.12.2021	CN 202121969293 U	Temperature adjusting device for greenhouse	SHAANXI PENGDA IND CO LTD	0	0	Y02A40/25
72	31.12.2021	CN 202111319336 A	Energy-saving and environment-friendly agricultural greenhouse	CHE LINJIE	0	0	A01G9/14, A01G9/243, A01G9/18, A01G9/241, A01G9/26, Y02A40/25, Y02P60/14
73	31.12.2021	CN 202111245616 A	Environment monitoring system for greenhouse crop planting	UNIV ANHUI AGRICULTURAL	6	0	A01G9/247, A01G9/24, A01G9/14, Y02A40/25
74	31.12.2021	CN 202111200691 A	Scanning type lighting device and method for agricultural lighting	INST OF URBAN AGRICULTURE CHINESE ACADEMY OF AGRICULTURAL SCIENCES	6	0	A01G7/045, A01G9/249, A01G9/246, A01G9/24, F21V14/02, F21V9/32, F21Y2115/10, Y02A40/25, Y02B20/40, Y02P60/12, Y02P60/21
75	31.12.2021	CN 202120937124 U	Ventilation layered storage device for potato breeding	TANG WENHUI	0	0	Y02A40/25
76	31.12.2021	CN 202120042909 U	Intelligent sightseeing greenhouse for planting vegetables and fruits	LUO JIANYONG	0	0	Y02A40/25
77	31.12.2021	CN 202111290148 A	Forest seedling raising device	SHENZHEN CHINA SKY LASER TECH CO LTD	0	0	A01G9/16, A01G9/24, A01G9/247, A01G9/249, A01G7/045, A01M7/005, B05B15/25, B08B9/087, Y02A40/25
78	31.12.2021	CN 202121634862 U	Clematis florida growth monitoring system	YU WEIJUN	0	0	Y02A40/25

No	Publication Date	Application Number	Title	Applicants[1]	Cites Patent Count	Cited by Patent Count	CPC Classifications
79	31.12.2021	CN 202120234455 U	Visual cultivation device for apple tree seedling culture	SHAANXI SEEDLING GROUP CO LTD	0	0	Y02A40/25
80	31.12.2021	CN 202022364307 U	Greenhouse built by fly ash phase change foamed concrete slabs	UNIV NINGXIA	0	0	Y02A40/25
81	31.12.2021	CN 202121395550 U	Container three-dimensional seedling raising device	DIANKAI CHANGZHOU NEW ENERGY TECH RESEARCH INSTITUTE CO LTD	0	0	Y02A40/25
82	31.12.2021	CN 202120636466 U	Irrigation auxiliary device for crop planting	NONGXIN INTELLIGENT TECH SHANDONG CO LTD	0	0	Y02A40/25
83	31.12.2021	CN 202120311578 U	Environment-friendly and energy-saving greenhouse	HUNAN HANTANG AGRICULTURE CO LTD	0	0	Y02A20/108, Y02A40/25, Y02P60/14
84	31.12.2021	CN 202111231548 A	Omnibearing three-dimensional light supply planting bin for plants	INST OF URBAN AGRICULTURE CHINESE ACADEMY OF AGRICULTURAL SCIENCES	0	0	A01G9/16, A01G9/246, A01G9/249, Y02A40/25
85	31.12.2021	CN 202121395556 U	Container three-dimensional planting device	DIANKAI CHANGZHOU NEW ENERGY TECH RESEARCH INSTITUTE CO LTD	0	0	Y02A40/25
86	31.12.2021	CN 202121495369 U	Intelligent illumination control device for greenhouse	HENAN YUTUO AGRICULTURAL TECH CO LTD	0	0	Y02A40/25
87	31.12.2021	CN 202111266331 A	Saline-alkali land fishery-agriculture comprehensive planting and breeding pond	ZHAO BEN	11	0	A01G9/14, A01G9/247, A01K63/003, A01K63/006, A01K63/045, E03B3/02, Y02A20/108, Y02A40/25
88	31.12.2021	CN 202111314124 A	Greenhouse protection system	CHANGSHA SUYAN AGRICULTURAL TECH CO LTD	0	0	A01G9/14, A01G9/22, Y02A40/25

No	Publication Date	Application Number	Title	Applicants[1]	Cites Patent Count	Cited by Patent Count	CPC Classifications
89	31.12.2021	CN 202121743172 U	Three-dimensional planting device for greenhouse	ANQING RUNJIA ECOLOGICAL AGRICULTURE TECH DEVELOPMENT CO LTD	0	0	Y02A40/25
90	31.12.2021	CN 202111191805 A	Rootstock feeding method and device for melon and fruit grafting	HEFEI JIAFUTE ROBOT TECH CO LTD	8	0	A01G2/30, A01G2/32, A01G2/38, Y02A40/25
91	31.12.2021	CN 202111241523 A	Energy-saving agricultural greenhouse	RUNTAI LINGTAN INNER MONGOLIA AGRICULTURAL TECH CO LTD	6	0	A01G9/243, A01G9/245, A01G9/246, Y02A40/25, Y02P60/14
92	30.12.2021	IL 2021050748 W	SYSTEM, DEVICE AND METHOD FOR IMPROVING PLANT GROWTH	BIOSOUND LTD	8	0	A01G7/04, H04S7/301, H04S2400/13, H04R2430/01, H04R3/12, A01G9/24, G10K15/02, Y02A40/25
93	30.12.2021	US 2020/0039016 W	SYSTEM AND METHOD FOR PASSIVE SOLAR HOUSES, BUILDINGS AND SKYSCRAPERS WITH INTEGRATED AQUAPONICS, GREENHOUSE AND MUSHROOM CULTIVATION	VILLAMAR CARLOS R	8	0	A01G18/60, A01G31/02, A01G9/26, A01G9/243, A01G9/18, A01K63/00, Y02A40/25, Y02P60/12, Y02P60/21
94	30.12.2021	EP 2021067369 W	AIR DUCT FOR DISTRIBUTING AIR IN A GREENHOUSE	COOLING GLOBAL S R O	1	0	A01G9/246, F24F13/02, F24F13/072, B29C53/40, Y02A40/25
95	30.12.2021	KR 20200127265 A	Hybrid power generation system using forest residues	JEON HO GEON	4	0	Y02A40/25
96	30.12.2021	US 202117400111 A	Radiator and Plant Illumination Lamp	FUJIAN SANAN SINO SCIENCE PHOTOBIOTECH CO LTD	0	0	A01G9/249, F21V29/83, F21Y2115/10, F21S4/28, F21S8/061, Y02P60/14, Y02A40/25, A01G9/249, A01G7/045, F21V29/713, F21V29/76

No	Publication Date	Application Number	Title	Applicants[1]	Cites Patent Count	Cited by Patent Count	CPC Classifications
97	30.12.2021	KR 20200002174 U	Heating Film With A Safety Pin	권혜경, 이대규	2	0	Y02A40/25, A01G9/1438, A01G2009/1461
98	30.12.2021	US 202016909628 A	CENTRALIZED PREDICTIVE CONTROLLER FOR MANAGEMENT AND OPTIMAL OPERATION OF MICROGRID POWERED GREENHOUSES	UNIV QATAR	0	0	G05B13/048, A01G9/24, Y02E10/50, Y02E70/30, Y02A40/25, Y02P60/12, A01G9/26, G05B13/048, A01G9/247, A01G9/18, H02S10/20, A01G9/241, A01G9/243, A01G9/246, H02S10/12, A01G9/249, A01G9/24
99	29.12.2021	KR 20200075065 A	Integrated monitoring and control system of smart greenhouse	DAHAM CO LTD	5	0	Y02A40/25, G06Q50/02, G06Q50/10, A01G9/24, A01G9/26, A01G9/246, A01G9/247, A01G9/249, A01G9/143, B08B1/005, B08B1/02, G05B19/05, G05B19/0405
100	29.12.2021	KR 20190132122 A	AGRICULTURAL SMART GREENHOUSE	충청북도 (관리부서:충청북도 농업기술원)	0	0	Y02P60/14, Y02A40/25, A01G9/14, A01G9/1407, A01G9/24, A01G9/242, A01G9/227, A01G9/246, A01G9/243, G06Q50/02

APPENDIX B: Table of the total number of patents of the applicants within the patents acquired in the research data sample (First 50 entries)

No	Applicant Name[1]	Number of Patents Counted
1	GROW SOLUTIONS TECH LLC	455
2	EASTMAN CHEM CO	179
3	OCADO INNOVATION LTD	99
4	HAYGROVE LTD	76
5	UNIV CHINA AGRICULTURAL	75
6	REPUBLIC KOREA MAN RURAL DEV	69
7	ASAHI GLASS CO LTD	67
8	UNIV SHENYANG AGRICULTURAL	64
9	SVENSSON LUDVIG AB	62
10	LG ELECTRONICS INC	55
11	PANASONIC IP MAN CO LTD	50
12	REPUBLIC KOREA MAN RURAL DEV ADMIN	49
13	GREEN PLUS CO LTD	49
14	UNIV NORTHWEST A&F	46
15	DOW AGROSCIENCES LLC	46
16	대한민국	45
17	TOTO KOGYO KK	44
18	SHENZHEN QIANHAI HONGJIA TECH CO LTD	44
19	UNIV SHANDONG AGRICULTURAL	43
20	SEIWA CO LTD	42
21	HOUWELING NURSERIES OXNARD INC	41
22	KONINKL PHILIPS ELECTRONICS NV	41
23	GLASSPOINT SOLAR INC	38
24	MJNN LLC	38
25	PORTER DAVID S	38
26	CONNELL GARY W	38
27	PLANTS LABORATORY INC	37
28	UNIV SICHUAN AGRICULTURAL	37
29	CRAWFORD EMMETT D	37
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32	UNIV QINGDAO AGRICULTURAL	35
33	ROHM & HAAS	34
34	VALK SYSTEMEN BVVD	34
35	KOREA INST ENERGY RES	33

[1] The names of the applicants are written exactly as stated in the patent documents.

No	Applicant Name[1]	Number of Patents Counted
36	UNIV NANJING AGRICULTURAL	33
37	Москвитин Петр Сергеевич	32
38	BEIJING RES CT INTELLIGENT EQUIPMENT AGRICULTURE	31
39	KOREA INST SCI & TECH	31
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41	AGNETIX INC	30
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44	SUMITOMO METAL MINING CO	29
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46	SUMITOMO CHEMICAL CO	28
47	PANASONIC CORP	28
48	UNIV KUNMING SCIENCE & TECH	28
49	YOSHITAKE KAZUO	27
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