Microplastic Impact on Plant: Review Paper Using VOSviewer

Marchel Putra Garfansa[1], *Lili* Zalizar[2,*], *Roy* Hendroko Setyobudi[3], *Shazma* Anwar[4], *Syarief* Husen[2], *Joko* Triwanto[2], *Iswahyudi* Iswahyudi[1], *Satriyo* Krido Wahono[5], *Bayu* Agung Prahardika[6], *Muhammad* Basyaruddin[6], *Thontowi* Djauhari Nur Subchi[2], *Fauziyah* Eni Purwaningsih[1], *Jaftiyatur* Rohaniyah[1], *Yenni* Arista Cipta Ekalaturrahmah[1], *Kustiawati* Ningsih[1], M*ohammad* Shoimus Sholeh[1], *Muhmammad* Taufiq Shidqi[1], *Ahmad* Labib[6], *Titan* Memory Yuhana[6], and *Lia* Kristiana[1]

[1]Universitas Islam Madura, Pamekasan 69317, Madura, East Java, Indonesia
[2]University of Muhammadiyah Malang, Malang 65144, East Java, Indonesia
[3]Plant Production and Biotechnology – PT Smart Tbk., Bogor 16810, West Java, Indonesia
[4]University of Agriculture, Peshawar 25130, Khyber Pakhtunkhwa, Pakistan
[5]Research Center for Food Technology and Processing (PRTPP), National Research and Innovation Agency (BRIN), Special Region of Yogyakarta 55861, Indonesia
[6]The State Islamic University of Maulana Malik Ibrahim, Malang 65144, East Java, Indonesia

Abstract. Plastic waste is now a major environmental problem worldwide, and it has worsened in the last few years. Scientists are studying how much plastic is in the environment, how dangerous it is, and how to learn it. This study looked at research papers on microplastics' effects on plants listed by Scopus from 2011 to 2022. The goal was to see how this body of knowledge has grown and expanded over time and guess what it will do. The authors used the VOSviewer package and Scopus analytics for the bibliometric study. A total of 380 manuscripts, written by 159 authors, were taken out. Much study is being done on particle size, quantity, bioaccumulation, and environmental and community effects. Rillig, M.C., Das Berlin-Brandenburgisches Institut für Biodiversitatsforschung, Germany, is thought to be the most productive and often-cited researcher. The Ministry of Education China is the most essential printing house. China is the leader in terms of the number of papers and study partnerships. It is best to look at the International Journal of Pharmaceutics.

Keywords: Bibliometric analysis, environmental problem, quantitative study, scientific mapping, systematic literature review

1 Introduction

Plastic pollution has emerged as a significant environmental concern globally recent days. Since the advent of industrial-scale plastic manufacture in 1950, there has been a consistent

* Corresponding author: lily@umm.ac.id

annual increase in global plastic output, reaching a staggering 367 × 10^6 in 2020 on a global scale [1] and predicted increase every year. Plastic trash has become a pervasive environmental problem on a global scale due to its extensive consumption, inadequate disposal practices, and suboptimal rates of recycling [2–4]. Despite its inherent durability, none of the plastic garbage now available in the market exhibits degradability in the natural environment. Furthermore, recycling or downcycling of plastics involves reclaiming polymers for lower value applications, has been limited to less than 10 % of the total plastic production [5]. Consequently, there is a concerning accumulation of plastic trash in the environment. The disposal of plastic garbage into natural lakes and rivers results in the processes of embrittlement, fragmentation, and photodegradation. The plastic trash undergoes ongoing fragmentation through physicochemical and biological degradation within the environment, resulting in the formation of Microplastics (MPs) when the plastic size is less than 5 mm [6, 7]. MPs may potentially exert detrimental impacts on aquatic organisms, and in certain instances, they might infiltrate tissues and cells, leading to adverse consequences.

The primary sources of MPs consist of particles derived from Polyethylene (PETE), Polypropylene (PP), and Polystyrene (PS) found in cosmetic and medicinal items [8]. The sale of beauty products that include MPs has been prohibited in some countries, such as Canada and the United States, due to the detrimental impact they have on the environment [9]. Secondary MPs are generated through several physical, chemical, and biological mechanisms that lead to the fragmentation of plastic waste [10]. The photooxidation of plastic is catalyzed by exposure to ultraviolet (UV) radiation, resulting in the brittleness and fragmentation of the plastic into MPs. The combination of high temperatures, sunlight exposure, and sufficient aeration creates optimal conditions for the production of MPs through repetitive fragmentation processes. Conversely, in aquatic environments and sediments characterized by low temperatures and lack of oxygen, the degradation of plastic particles occurs at a significantly slower rate, potentially lasting for centuries [11]. MPs are found in many morphologies, including pellets, fibers, and fragments, in environmental samples due to the influence of different sources [12].

MPs research has seen a substantial increase in recent years, with a focus on abundance, toxicological effects, and analysis methods [13]. The research areas relating to MPs include distribution, sources, toxic effects, analytical approaches, and adsorption with other pollutants [14]. Although the recent surge in research efforts, there remains a dearth of comprehensive worldwide understanding of the magnitude of water pollution caused by MPs and their consequential impacts on species and ecosystems [15]. To date, the majority of research efforts have mostly concentrated on the examination of MPs contamination in terrestrial ecosystems, as well as the consequences of MPs on environmental ecotoxicology and the performance of plant [16].

Microplastic impact on plants has been a topic of interest in recent studies. The presence of MPs in contaminated soils has been found to have toxic effects on plant growth, including impaired root and shoot growth, reduction in leaf size, chlorophyll content, and photosynthetic efficiency, as well as changes in the elemental profile [17]. MPs can also affect the soil-plant system by altering soil aggregates, nutrient cycling, and the balance of plant chlorophyll a/chlorophyll b ratios, leading to reduced rooting ability and photosynthetic rate [18]. Additionally, MPs have been shown to inhibit seed germination processes in herbaceous ornamental plants, affecting germination rates, root formation, and various physiological and biochemical indicators [19]. The effects of MPs on soil properties and biological function in the rhizosphere are highly variable, with impacts on erosion-risk, structural integrity, water-storage capacity, and rhizosphere function [8]. Previous review articles have provided a summary of the research on the impact of MPs on plants, but their conclusions are based on a limited number of publications. However, there is still a lack of understanding regarding the migration of MPs within plants and their effects on growth and metabolism. It is necessary to systematically summarize and reassess this topic, particularly in light of the increasing number of new findings in recent years.

Bibliometric analysis is a systematic approach that employs statistical techniques, data mining, and mathematical methods to discern emerging trends within a specific research domain. Currently, there is a growing trend in its adoption and application across multiple academic disciplines [20]. By employing this approach, the scientists were able to identify prevalent themes in the impact of MPs on plants, including plant development, ecosystem dynamics, particle size, and bioaccumulation. These findings suggest that further investigation in these areas holds potential for future research endeavors. Therefore, the current study involved a comprehensive review of all available scholarly articles pertaining to the influence of MPs on plants from 2011 to 2022. The objective was to analyze the growth and progression of this field of research and provide predictions regarding its future trajectory.

2 Methodology

2.1 Bibliometric

Bibliometric studies [21, 22] use a number of mathematical and statistical methods to look at library data. The bibliometric review method tries to figure out how journal mentions affect research success and gives a short description of where a busy or growing research area is right now. Bibliometric analyses get the data they need for a bibliometric study from citation sources like Scopus and Web of Science [23]. Managing this kind of data can also be done with other study methods, like meta-analysis. Meta-analysis and bibliometric analysis are both ways to do a quantitative study. In contrast to a meta-analysis, the studies in a bibliometric analysis can be very different from one another. Furthermore, bibliometric studies only look at the numbers of things about an article, like its publications, links, keywords, and authors, and how they connect with each other. But this needs to look at the links between the actual results of papers and the common use of meta-analysis in linked research areas. But, both ways might help explain the problem of the state-of-the-art study as well as the present field's trends and goals. The new bibliometric study used the following measures, which were explained in the parts that follow [23, 24].

2.2 Determining the study's scope and data collection

The first thing that bibliometric research looks at is the size of the study. Before the research can start, it needs to be made clear what it will look into and how many studies will be looked at. If not, the findings would be bad, full of mistakes, and not in line with the main goal of the study. It is very important to carefully look over the buzzwords that were used to collect the data.

2.3 Sample size and data extraction

Also, bibliometric analysis should be thought about when there is a lot of bibliometric data and the literature review is too broad to be studied by hand. Bibliographic analysis is only suggested when there are at least 200 papers to look at in the sources [25]. It was found that bibliometric studies with smaller sample numbers (200 papers) had very different average category-standardized citation effects. This means that this method is not good. Because of this, the current study looked at both phrase screening and trial-and-error methods. The sample size was found to be right for the bibliometric analysis. A very important part of the bibliometric study was choosing the right source to gather data from the books. As was said, the data for this study came from the Scopus database and were saved in a Microsoft Excel file extension called ".csv" [26].

2.4 Bibliometric analysis

Every bibliometric study is built around three main ideas: measuring performance, analysing networks, and making scientific maps. Performance analysis is a way to find out facts about publishing and citations, like how many papers have been published and how many times they have been cited (h-index) [27]. Hirsch says that a scientist has a h index if h of his or her Np papers have at least h citations each and all of his or her other Np - h papers have at least h citations each [28]. Science mapping, also known as bibliometric mapping, looks at the effects and levels of links between different aspects of an article by using the item's co-occurrence weight and total link strength. Citation analysis, bibliographic linking, co-citation analysis, co-word (keyword) analysis, and co-authorship studies are some of the methods that make up this group. The results of bibliometric mapping can be made better by using network analysis. Metric evaluation, grouping, and visualisation are all common methods used in network analysis. Scopus statistics, including the number of publications, the number of papers published each year, the number of links, and the h-index, were used to support the performance analysis in this study. Performance analysis was used to rate research work linked to SLNs using Scopus analytics features. The data file was also used with the VOSviewer programme to do science mapping and network analysis [29]. In bibliometric studies, the VOSviewer is being used more and more. This programme was made by van Eck and Waltman [30] to make it easier to make and show readable bibliometric maps. It does a great job of finding important information, finding similarities between publications that meet the same criteria, and finding the main theme that runs through all of the chosen papers. VOSviewer also has three different ways to view: network visualisation, overlay visualisation, and density visualisation. They only used network visualisation because it quickly showed how different keywords and book themes are connected by things like co-occurrences, co-authorship, and place of origin. It also uses colour to show how commonly and closely a study is linked to other studies. As a word is used more in more than one area of study, the line that connects them becomes more noticeable. If the hue is light, on the other hand, it means the link is weak [29–31].

3 Result and discussion

3.1 Bibliographic extraction

The following keyword combination was input into the Scopus website's search bar (https://www.scopus.com/) [TITLE-ABS-KEY (“Microplastic Impact on Plant”) AND (LIMITO (DOCTYPE, “ar”) OR LIMIT TO (DOCTYPE, “cp")) AND (LIMIT-TO (LANGUAGE, “English")]. Table 1 shows that this literature search turned up 380 study documents, no matter the years, languages, sources, or documents. There are articles, reviews, book chapters, conference papers, notes, opinions, and conference reviews in this collection from 2011 to 2022. From 2011 to 2022, 380 papers were released, which is the same number as the total amount of study work listed by Scopus.

Due to the minimal literature examining the effects of MPs in agricultural environments, there are not many research papers in this field. Environmental and agricultural professionals have investigated the origins of MPs, the process by which they enter plant tissue, the impact of MPs on plant growth, and the long-term effects of human consumption. Understanding the effects and mechanisms of MPs' effects on higher plants is aided by information on the impact of MPs on plant growth [32].

Table 1. Bibliographic extraction.

Type of documents	2011 to 2022	
	Number	**Percentage**
Article	240	63
Review	119	31
Book chapter	10	2.7
Conference paper	4	1.1
Note	5	1.4
Editorial	1	0.4
Conference review	1	0.4
Total	380	100

3.2 Overview of research performance

Before the Scopus-sorted papers were mapped bibliometrically, they were checked to see how productive they were. This way gives a detailed look at how different factors (like terms, article groups, writers, institutions, countries, and journals) work in Scopus results. This study showed the number of publications each year, the number of citations each year, the h-index, the most-cited papers, and the most-relevant publications. The "document search results" from Scopus were used to put this information together. To figure out how useful study is in a certain area, you need to look closely at how often science articles are published each year. Table 2 shows the number of articles published each year from 2011 to 2022, which adds up to 380 publications. Most of the 162 works that came out in 2022 were in the journals Science of the Total Environment and Environmental Pollution. These two magazines print studies on the effects of MPs on plants because they are interested in waste in the environment.

Table 2. Publication performance analysis.

Year	Number of articles	Citation
2022	162	2 448
2021	96	4 373
2020	63	5 520
2019	30	6 933
2018	16	5 982
2017	6	1 536
2016	3	1 221
2015	1	148
2014	1	4
2013	1	284
2012	0	0
2011	1	3 318

Citation counts figure out how important a piece of writing or an author is by counting how many times it is cited in other works. Citations for years are shown in Table 2 and for research works they are shown in Table 3. The most mentions were found in 2019 and 2018, compared to other years. Because so few science studies came out that year, it was the most important year for microplastic effect on plant study. The paper that was released in Biological Reviews has been cited the most [33]. The researchers in this academic discussion talk about dangers and ongoing protection problems for plant and animal life in waterways. They list 12 new threats to freshwater species that have either come up since 2006 or have gotten worse since then: (i) climate change; (ii) e-commerce and invasions; (iii) infectious diseases; (iv) harmful algal blooms; (v) growing hydropower; (vi) new contaminants; (vii) engineered nanomaterials; (viii) microplastic pollution; (ix) light and noise; (x) rising salt levels in freshwater; (xi) falling calcium levels; and (xii) stressors that build up over time. There are effects on frogs, fish, insects, bacteria, plants, turtles, and waterbirds. Changes at the ecosystem level may happen through both bottom-up and top-down processes. The combined effects of these threats are very worrying for ecosystems that live in fresh water. But they also point out chances for conservation gains through new management tools (like environmental flows and DNA) and specific conservation-focused actions (like removing dams, enforcing habitat protection policies, and managing the relocation of species), which have had varying degrees of success. As of 2019, the most research had been done on MPs. Researchers from all over the world are now studying their effects and risks to living things, which is why this scientific work has been cited a lot.

Table 3. Top-cited articles.

Rank	Title of the article	Year	Total citation	Ref
1	Emerging threats and persistent conservation challenges for freshwater biodiversity	2019	1 332	[33]
2	Microplastics can change soil properties and affect plant performance	2019	809	[34]
3	Release of synthetic microplastic plastic fibres from domestic washing machines: Effects of fabric type and washing conditions	2016	757	[35]
4	Microplastics en route: Field measurements in the Dutch river delta and Amsterdam canals, wastewater treatment plants, North Sea sediments and biota	2017	676	[36]
5	Occurrence, identification and removal of microplastic particles and fibers in conventional activated sludge process and advanced MBR technology	2018	645	[37]
6	Evidence of microplastic accumulation in agricultural soils from sewage sludge disposal	2019	631	[38]
7	Macro- and micro- plastics in soil-plant system: Effects of plastic mulch film residues on wheat (*Triticum aestivum*) growth	2018	579	[39]
8	Microplastic in the surface waters of the Ross Sea (Antarctica): Occurrence, distribution and characterization by FTIR	2017	387	[40]
9	Microplastics accumulate on pores in seed capsule and delay germination and root growth of the terrestrial vascular plant *Lepidium sativum*	2019	362	[41]
10	Selective enrichment of bacterial pathogens by microplastic biofilm	2019	340	[42]

MPs getting into the ocean have been a growing problem since the 1940s, when plastics started being made in large quantities. The following goals were set for the literature review: (i) to talk about MPs' properties, names, and where they come from; (ii) to talk about how MPs get into the marine environment; (iii) to talk about how MPs are found in the marine environment; (iv) to talk about the changes in the amount of MPs over time and space; and (v) to talk about the effects of MPs on the environment. MPs are everywhere in the ocean, but there are the highest amounts near the shore and in the middle of the ocean. Many marine creatures have been seen to eat MPs, which could make it easier for chemical agents or watery toxins that don't dissolve in water to reach biota. Marine life, including fish and plants, are polluted by all the trash that runs through the air. Plastic trash pollution is getting worse and is ending up in the ocean. That's why it's not a surprise that this research study has been cited a lot.

The second cited article was published by Napper and Thompson (Table 3) [34]. Six types of MPs were studied: polyester threads, polyamide beads, and four fragment types (polyester terephthalate, polypropylene, and polystyrene). The effects on a wide range of indicators for soil health and performance of the spring onion (*Allium fistulosum* L.) were described. There were big changes in the amount of plant matter, the elements in the tissue, the root structure, and the actions of microbes in the soil. These reactions from plants and dirt to MPs were used to come up with a model for how the effects work. Effects depended on the type of particle. For example, MPs that looked like other earth particles had smaller effects compared to the control group. The results showed that polyester fibers and polyamide beads had the most noticeable effects on plant traits and function. This could be because they changed the structure of the soil and the way water moved through it. The results presented here suggest that the widespread presence of MPs in soil may have effects on plant health, which in turn may have effects on agroecosystems and land biodiversity. To reverse global trends in freshwater degradation, conservation biologists must bridge a vast chasm between their aspirations and the accelerating rate of species extinction. From 2011 to 2022, the number of authors in the field of microplastic impact on plant was approximately 159. Rillig, M.C. has the most publication and citations, with six and 1 673, respectively. Rillig, M.C. is (h-index = 102) affiliated with Brandenburgisches Institut für Biodiversitätsforschung, Germany. Ministry of Education China is the top publishing academic organization (n = 35), followed by Chinese Academy of Sciences, University of Chinese Academy of Sciences, Ministry of Agriculture of the People's Republic of China, and Northwest A&F University, respectively. It is evident from these citations, which represent the foundation of knowledge and serve as the basis for subsequent research emanating from specific nations. One plausible explanation for this phenomenon is the expansion of scientific.

In the academic discussion about MPs' effects on plants, Table 4 shows the most-cited and written sources. The h-index, citescore, amount of documents, and overall link strength for the top ten journals are shown. It is the Marine Pollution Bulletin that has the most information on how MPs affect plants. The influence of this magazine is also clear from the fact that it has the most articles (1 115) and citations (4 839), though not the highest citescore. The Marine Pollution Bulletin is getting this educational boost because it is at the top of the lists for microplastic study.

Table 4. Top-cited sources.

Source		Documents	Citations	Journal's h-index	Journal's citescore 2022
1	Marine pollution bulletin	1 115	4 839	23	10.1
2	Biological reviews	99	1 196	19	23.5
3	Global change biology	525	4 373	26	19.5
4	Water research	1 294	11 628	35	19.8
5	Environmental science and technology	1 800	13 319	37	16.7
6	Science of the total environment	8 237	66 899	53	16.8
7	Environment international	741	6 290	26	22
8	Environmental pollution	1 991	13 582	33	14.9
9	Chemosphere	4 826	47 165	57	13.3
10	Environmental toxicology and chemistry	276	867	11	6.3

The Marine Pollution Bulletin also got the following h-graph from Scopus, which shown in Figure 1. The total number of mentions for each article is shown on the horizontal line, going from most to least. The total number of mentions is shown as a positive figure on the vertical line. There is a direct link between the papers and the total number of sources when there is a 45-degree line. The h-index, or hirsch index, is shown by a star where the 45-degree line meets the citation/document slope. It shows how important the written pieces are. The h-index is used in this study as a mathematical way to figure out how useful and productive the Scopus article collection is. The results show that Marine Pollution Bulletin (2012 to 2022) has an h-index of 23. The number 23 means that 23 of the 23 items have been mentioned at least 23 times.

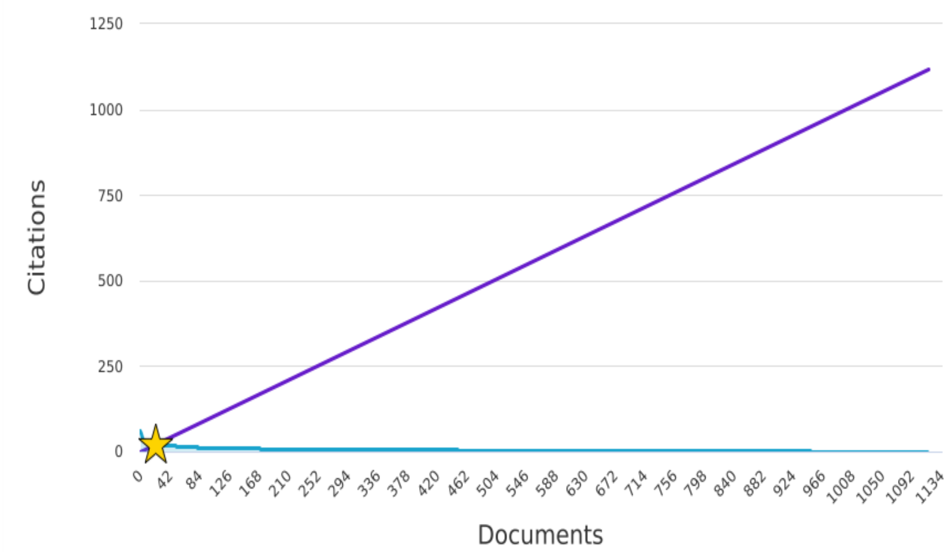

Fig. 1. h-index graph of the citation for marine pollution bulletin.

3.3 Bibliographic mapping

Bibliographic mapping technologies are capable of handling the vast amounts of data produced by the quick speed of research by making it easier to track the development of new trends and the status of ongoing studies. VOSviewer was used to do the final data output display and bibliographic mapping. After being reviewed, changed, and checked by the VOSviewer, the final article database was used for bibliographic mapping with in-app algorithms to make the visual file. VOSviewer, an open-source Java application that facilitates trend analysis via bibliometric map display, was used for this purpose [43]. After identifying study clusters using a co-occurrence analysis of the articles' keywords, the visualization looked into the new research trend. The main ideas and advancements of each article's research subject were represented by keywords. For knowledge mapping, a keyword co-occurrence network is useful since keywords show how a study subject develops as well as the actual content of an article. The author's keywords in the literature database determine the co-occurrence frequencies in the VOSviewer.

In all, 457 keywords were employed by the writers across 380 research papers. The most common keywords, with a total link strength of 5 423 and 793 occurrences, are shown in Table 5. Merely 68 individuals fulfilled the need of being mentioned in a minimum of twenty publications, resulting in a statistical frequency of 14 % (68/457). The idea behind implementing this minimum keyword occurrence rate is that the more often a phrase appears, the more well-liked the study topic is. Using VOSviewer software, the keywords of these writers were mapped into six clusters (Figure 2) after using the full count approach.

Table 5. Most highly occurring author's keywords.

Keywords		Cluster	Occurences	Total link strength	Link
1	Microplastic	4	174	921	54
2	Environmental impact	5	163	220	12
3	Ecosystem	1	161	206	18
4	Particle size	3	54	164	36
5	Environmental monitoring	4	58	309	29
6	Microplastic pollution	3	47	87	15
7	Concentration (composition)	2	40	117	31
8	Concentration (parameter)	2	33	88	16
9	Bioaccumulation	5	29	108	12
10	Plant growth	3	34	3 203	478

VOSviewer makes two different maps for showing the network and the layer. A two-dimensional distance-based map is used in both images to show how closely the items are connected based on their distance. More distance and less distance between two things show connections that are stronger. On the other hand, a shorter space means a stronger tie.

It's marked with a name and a circle, the size of which shows how important the keyword is. The reference mapping for overlay visualization and network visualization is the same, even though different colors stand for different types of information. The overlay visualization shows how often each term is published on average each year, while the network visualization shows information about keyword cluster groups. Here's a look at the five study groups that can be seen in network visualization:

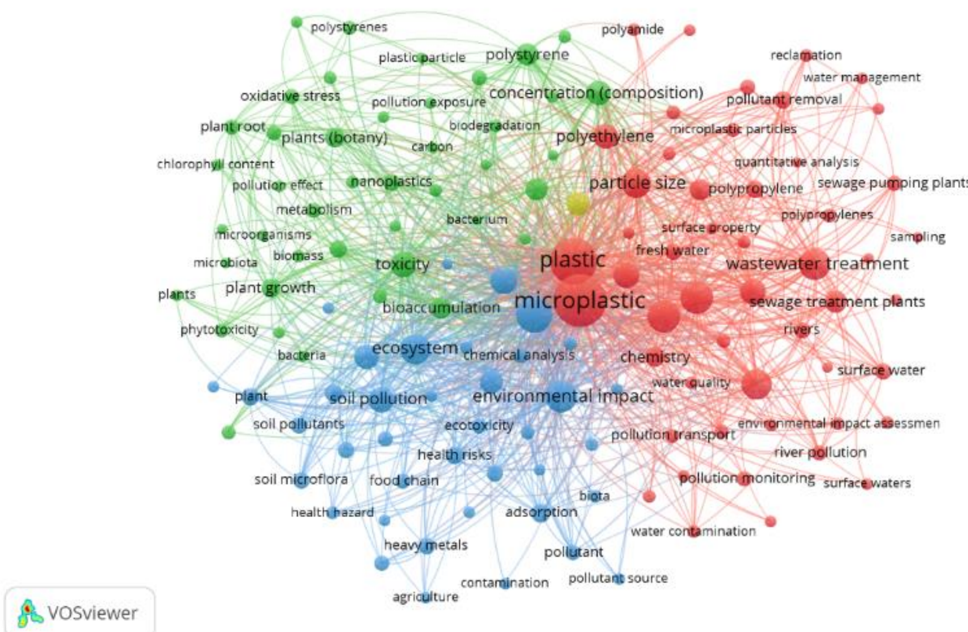

Fig. 2. Representation of the author's keyword network showing co-occurrence.

Note: Circles represent the number of co-occurrences of keywords. Clustering was performed using VOSviewer software.

The first cluster (shown in red) includes terms such as "Microplastic," "Environmental monitoring", "Water pollutant", "Polyethylene", and "Reclamation". The inset plot shows how the terms in this group have changed over time since 2015. The keywords "Microplastic" and "Environmental monitoring" trended with an average of 2 020.21 and 2 019.41 (Figure 3).

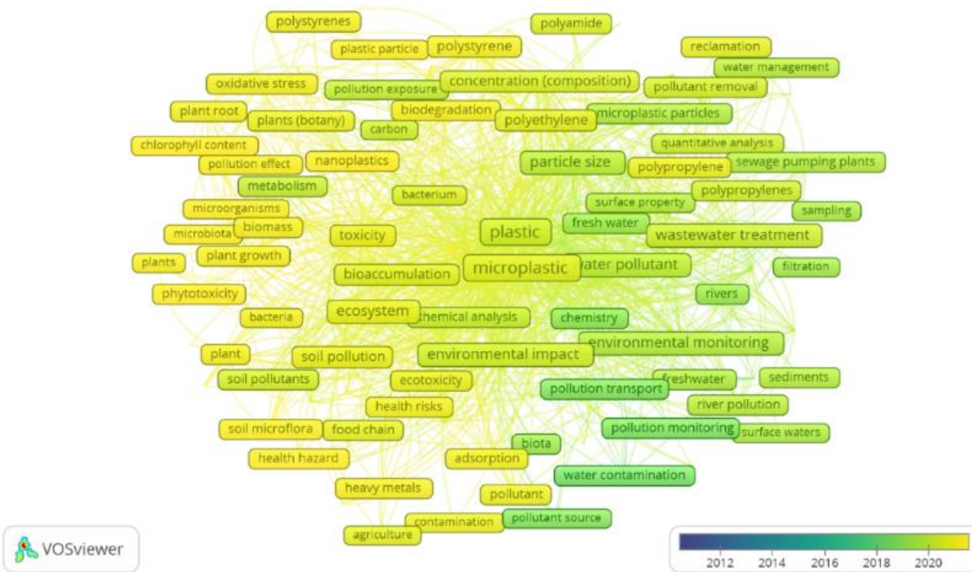

Fig. 3. Keyword's overlay visualization of co-occurrence based on average publications per year.

Note: Keywords with different colors differ in their emergence

Cluster 2 (green) consisted of 43 keywords. "Concentration (parameter)", "Concentration (composition)", "Plants (botany)", and "Polysterene" are the most frequently occurring keywords in this cluster. In the investigation of the impact of MPs on plants, scholars commonly assess the concentration of MPs within the soil or growing medium as a means to comprehend the scope of contamination. The significance of this concentration lies in its potential to exert a direct impact on both the growth and overall health of plants. In the context of these investigations, scholars may examine the impact of varying quantities of MPs, often sourced from substances such as polystyrene, on diverse facets of plant development. Polystyrene is frequently identified as a prevalent origin of MPs due to its propensity to undergo fragmentation into minute particles, which can then be assimilated by various plant species.

Cluster 3 (blue) focused more on the particle size, microplastic pollution, and plant growth. "Particle size" had the highest occurrence of 54 times, a total link stregth of 164, and 36 links. The keyword "Plant growth" represented this cluster with 34 occurrences. The word "Particle size" refers to the dimensions of tiny plastic particles comprising MPs, and it holds substantial influence in influencing the interactions between these particles, plants, and their surrounding environment. For example, it is possible that smaller microplastic particles have a higher likelihood of permeating plant tissues and thus disrupting the process of nutrient absorption. Conversely, larger particles may primarily impact the structure of the soil, its ability to retain water, and other qualities of the soil, which in turn indirectly affect the growth of plants. The comprehension of the correlation between the size of microplastic particles, the presence of microplastic pollution, and the growth of plants is of utmost importance in evaluating the ecological ramifications of microplastic contamination and formulating approaches to alleviate its potential adverse effects on plants and ecosystems.

Cluster 4 (yellow) was anchored by "Ecosystem" as seen in the network visualization. The interplay between ecosystems and the influence of MPs on plant life is a multifaceted and interdependent phenomenon. The infiltration of ecosystems by microplastic contamination, originating from many sources, presents substantial ecological concerns. Within the given framework, plants assume a pivotal function as primary producers and foundational organisms within ecosystems, serving as a central element for several trophic interactions.

Cluster 5 (purple) was led by the keyword "Environmental impact" representated this cluster with 163 occurrence and 220 total link strength. The complex correlation between the environmental ramifications and MPs highlights the pressing need for worldwide initiatives aimed at reducing their prevalence and promoting knowledge regarding the adverse effects of plastic contamination on ecological systems and biodiversity.

3.4 Geographical mapping and international collaboration

There were 68 countries that took part in the study on "Microplastic impact on plant." These are the most active countries, as shown in Table 6. This article has been cited 27 751 times. The 159 writers who wrote these 380 stories. China is the most productive country. The US and Australia are next. The United Kingdom was mentioned the most, with 24.46 % of all mentions coming from that country. China has made a lot of investments in microplastic study over the past 20 yr, which is why it is growing. Because China is such a major farming powerhouse, there are more academic studies looking into how MPs affect plants there. The agricultural sector in China serves as a fundamental pillar of its economy and assumes a crucial position in the context of global food production [44]. The growing emphasis on comprehending the impact of MPs on plant life in this expansive and agriculturally significant country is influenced by various pivotal reasons.

Table 6. Most cited and productive countries.

Country		Document	Citation
1	China	160	5 446
2	United States	48	3 637
3	Australia	34	3 345
4	United Kingdom	32	6 789
5	Germany	27	3 955
6	India	26	580
7	Italy	21	815
8	Canada	20	1 624
9	South Korea	17	1 379
10	Portugal	12	181

The substantial population of China exerts significant strain on its agricultural systems in order to satisfy the dietary requirements of billions of individuals [45]. Therefore, it is imperative to prioritize any element that has the potential to impact crop productivity and food security. The presence of MPs poses a significant threat to soil health and nutrient cycling, hence exerting a direct influence on agricultural output. In light of China's efforts to address food security concerns and make substantial contributions to global food production, it becomes crucial to undertake a comprehensive examination of the impacts of microplastic pollution on crop cultivation.

3.5 Impact MPs on plant based on research collection

In several studies that have been carried out, MPs have been found to affect plants both directly and indirectly. MPs can change the micro ecosystem that has been formed. MPs impact both on soil aggregates and soil nutrient cycling within the soil-plant system. Additionally, it seeks to explore the synergistic impacts of MPs and other pollutants on soil-plant systems.

MPs have been shown to affect the chlorophyll (Chl) content in plants. They can reduce the photosynthetic rate by directly interfering with the balance of plant Chl a/b ratios [46, 47]. Higher concentrations of MPs have been found to significantly reduce the chlorophyll a content of freshwater microalgae [48]. The effect on the Chl content will affect the resulting photosynthesis rate. Huang *et al.* [49] showed that MPs can reduce the photosynthetic rate of plants by directly interfering with the balance of plant Chl a/b ratios. MPs affect the stability of aggregates by interfering with abiotic factors (*e.g.*, sesquioxide and exchangeable cations) or biotic factors (*e.g.*, soil organic matter and organism activities in the soil). For example, Chl contents and soluble sugar of cucumber were significantly decreased after exposure to 100 nm PS [50], and the leaf Chl content of maize was decreased after exposure to HDPE [51]. Moreover, MPs reduce Chl b synthesis in wetland plants [52]. However, several studies have shown an increase in Chl in certain conditions. The addition of MPs with increasing application rates and different sizes always reduced the concentration of leaf Chl [53]. Additionally, MPs (0.5 µm, 100 mg L^{-1}) increased Chl content in wheat seedlings when combined with heavy metals (copper and cadmium) [54]. These changes exhibited different trends for different MPs concentrations. The improvement effect of MPs on the photosynthetic pigments of plants was significant when the MPs concentration was low [(0 to 50) mg kg^{-1}] [55]. When the MPs concentration increased to 100 mg kg^{-1}, 5 µm MPs caused a significant decrease in the Chl and carotenoid contents, whereas 100 nm MPs did not have a significant effect. Furthermore, the total Chl content under the influence of 5 µm MPs showed a dose-dependent effect; with increasing MPs concentration, the total Chl content significantly decreased. The effect of MPs with different polymer compositions on photosynthesis in vascular plants differed. For example, in tests of *L. sativum* exposed to PETE, PVC, PETE + PVC, and PP, even though the photosynthetic pigments increased, the magnitude of the increase considerably varied [56]. Compared with single heavy metals treatments, the combination of PS MPs and heavy metals increased Chl content, enhanced photosynthesis and reduced the accumulation of ROS. The Chl content and Chl ratio were used as stress indicators. Chl content and Chl a/b ratio both had no significant differences between the control and single PS group. The increasing application rates of MP and small size HDPE significantly reduced the starch concentration in the leaves of Chinese cabbage, however, the different sizes of General Purpose Polystyrene (GPPS) showed limited effects on the leaf starch. The addition of MP with increasing application rates and different sizes always reduced the concentration of leaf Chl.

Since MPs affect the anchorage of nutrients to roots and Chl, impacts on plant biomass are possible. Studies have shown that exposure to MPs reduce microalgal biomass by decreasing single-cell weight and production of smaller-sized cells up to 52 %. This decrease in biomass is thought to be caused by the MPs triggering a stress response that might result in cell metabolism adaptions to produce less dense molecules or discharge stock molecules. Previous studies [57, 58] have demonstrated that microalgal cells exhibit alterations in their morphology, specifically in relation to the impairment of pyrenoids, thylakoids, plasma membranes, and the cell wall. These changes have been observed to potentially lead to a decrease in cell size [59]. Given the absence of any alterations in cell density, the observed decline in biomass productivity suggests that exposure to MPs may be affecting either the size or weight of microalgal cells, both of which were examined in this study. The observed reduction in root length could potentially be attributed to the an accumulation of MPs on both the seed capsule and the surface of the roots. This deposition may impede the absorption and/or uptake of essential nutrients and water [60, 41]. Significantly, favorable impacts were identified for several plant species, such as rice [61], wheat [62], cress [41], soybean, and mung bean [63]. Nevertheless, the observed augmentation in root biomass may potentially indicate a state of stress, as plants resort to expanding their root systems as a mechanism to adapt to challenging surroundings caused by the presence of MPs, as suggested by Boots *et al.* [64]. In order to mitigate the effects of stress, plants exhibit a physiological response by enhancing their growth in terms of both size and root system depth, so facilitating an improved absorption of water and nutrients. While there is variability in findings between studies, the prevailing trend is that the majority of cases demonstrate a detrimental effect on shoot length.

The impact of MPs on plant rooting ability has been demonstrated by heir influence on soil bulk density [65] and water-holding capacity [66]. Furthermore, MPs in soil can have adverse effects on root growth traits of plants, potentially reducing yields and causing damage to the food web [67]. On the contrary, it has been observed that MPs have a detrimental effect on the development of root systems [68, 39]. This negative influence significantly hampers the below ground growth of crops. Moreover, it has been observed that plastic particles have the potential to disrupt the development of root systems and impede the progression of root hairs, thereby limiting the absorption of nutrients [41]. MPs have the potential to influence the growth and functioning of plant roots, thereby impeding the absorption of water and nutrients. Urbina *et al.* [69] have documented the presence of adverse effects on the growth of plant roots when exposed to MPs in hydroponic systems.

The presence of MPs has been observed to have an impact on the stability of aggregates through its interference with both abiotic factors, such as sesquioxides and exchangeable cations [49], and biotic factors, such as soil organic matter and soil organism activities [70]. In addition, the presence of MPs has the potential to impact the process of soil nutrient cycling through its influence on the predominant bacterial phyla in the soil, as well as the genes and enzymes involved in the carbon, nitrogen, and phosphorus cycles [71]. The combined impact of MPs and other pollutants on plants manifests in two ways. Firstly, MPs that adhere to the surface of plant roots physically impede the interaction between the pollutants and the roots [72]. However, these MPs are more likely to intensify the detrimental effects of pollutants on plants. MPs to act as a carrier for heavy metals derived from the environment, disrupting the uptake and accumulation processes in plants. Mamathaxim *et al.* [73] in his research showed that the co-exposure of NPs/MPs + As (Arsenic) mitigated the rice growth inhibition caused by As toxicity.

MPs that possess comparable shape and size to soil particles exhibit relatively minor impacts, but microfibers, MPs of smaller dimensions, and biodegradable plastic particles demonstrate more pronounced effects. Moreover, effects of MPs on Chl content may vary depending on the types, concentrations, sizes, and shapes of MPs.These results will provide insight into elucidating the potentially effects of nano/MPs on uptake and accumulation in crop plants for assessing the hazards of micro-and nanoplastics as pollutants in the food chain and environment.

3.6 Research gap MPs on plant

Research on the effects of MPs on plants was a growing area of interest. Studies have shown that vascular plants can act as sinks for MPs and nanoplastics, with these plastics being adsorbed onto the surfaces of plants and even internalized by them [74]. MPs have been found to affect the soil-plant system by altering soil aggregates, soil nutrient cycling, and the combined effects of MPs and other pollutants on plants [49]. Accumulation and potential effects of MPs on crop plants have also been studied, highlighting the need for further research on the accumulation and translocation of MPs in edible plants and their impacts on food safety [75]. Moreover, current level of knowledge about the origins of pollution, pathways of migration, outcomes, and ecological hazards associated with MPs in vascular plant ecosystems [76]. The imperative of undertaking precise quantitative studies in replacement of broad qualitative evaluations is an essential undertaking for the future. The integration of hydrodynamic and physical models can be used to examine the underlying mechanisms involved in the migration of MPs [77]. It is imperative to provide a summary of the pertinent mechanisms, drawing from both theoretical and empirical evidence [78]. The understanding of the mechanisms behind the interaction between MPs and nanoplastics and vascular plants was currently limited [79]. The utilization of engineered nanoparticles and plastic films has been recognized as significant sources of pollution, exhibiting similar features to nanoplastics and MPs [80]. The expansion of research beyond the two-point methodology, which focuses on the initial and final stages, to encompass the entire growth phase, has the potential to elucidate the migratory mechanism of phytotoxicity in vascular plants [81].

4 Conclusion and recomendation

Concerns about the effects of MPs have been around for a long time. Several land habitats could be threatened by them, and plants may not look good around them. Additionally, more and more studies show that MPs are bad for plants. This is mostly because the plastic sticks to plant roots, which lowers the quality of the dirt because of the MPs. Using bibliometric analysis, this study looked at the current state and direction of the growth of research results on the effects of MPs on plants. The study looked at the performance of 380 articles from Scopus and found that this area of research really took off in 2011. The main areas of research that are being studied are environment effect, ecosystem, particle size, concentration, and bioaccumulation. Even though it's not one of the most popular topics at the moment, waste of farming practices on crops has become very famous very quickly and has been talked about more in the scientific community since 2018. The poll also found that China has made the most important advances to studies on the effects of MPs on plants. Also, there needs to be more research on the subject of the connection between microplastic particle size, microplastic pollution, and plant growth. This is important for figuring out the environmental effects of microplastic pollution and coming up with ways to protect plants and ecosystems from it.

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